

GROWTH AND CERTAIN ASPECTS OF THE
CHEMICAL COMPOSITION OF THE ONION
AS INFLUENCED BY NUTRITION

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This is to certify that the

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Growth and Certain Aspects of the Chemical Composition of the Onion as Influenced by Nutrition

presented by

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has been accepted towards fulfillment of the requirements for

Ph D degree in Horticulture

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Date March 1, 1955



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GROWTH AND CERTAIN ASPECTS OF THE CHEMICAL COMPOSITION
OF THE ONION AS INFLUENCED BY NUTRITION

By

JOHN D. DOWNES

A THESIS

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INTRODUCTION

Although information from field experiments in which various quantities of nutrients have been supplied to onions is considerable, the physiological effects of various nutrients on onion growth and nutrient accumulation have not been investigated. Studies have also emphasized the importance of separating plants into various portions for more completely evaluating physiological relationships and nutrient requirements, but no complete separate analyses for tops and bulbs of onions are to be found in the literature.

Information regarding the importance of the nutrients supplied to the mother bulb during its formation as reflected in its ability to produce abundant and viable seed under field conditions is lacking. Neither has the influence of the mineral content of onion sets on the yields of the subsequent bulb crop been thoroughly investigated.

In relatively few of the experiments designed to study the effects on plants of several nutrients simultaneously have single nutrients been varied alone.

This investigation was undertaken to study the influence of the addition of a number of nutrients upon their accumulation in onions, and to attempt to estimate the direction and magnitude of gross developmental variations associated with any differences in nutrient content.

LITERATURE REVIEW

Introductory

Much of the research done on the responses of onions to environmental factors has been conducted in the field allowing immediate application of the information obtained. Pot culture and similar methods have been used, based upon the idea that control of certain environmental factors of plant growth should allow more precise study of the effects of single factors, or the combination effects of a relatively few factors. Employment of these techniques has contributed information on the importance and interrelationships of both macro- and micro-nutrients. On the whole, however, pot and similar cultural techniques have tended to supplement rather than to supplant field investigation.

Nitrogen

Knott (54) concluded that most of the nitrogen required by onions is needed during the early phases of growth, and its application may result in early maturity by inducing adequate foliar growth prior to bulb initiation. Results obtained by Kunkel (58) confirmed the findings of Knott, and showed in addition that supplemental nitrogen was of most value in cold springs on wet acid muck soils. In a series of experiments, Ware and Johnson (94) found that onions gave steadily

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increasing yields with application varying from 0 to 120 pounds of nitrogen per acre. Results obtained by Wilson (95) indicated that a shortage of nitrogen is associated with lowered sugar production and perhaps also with delayed bulb initiation. Sugar was shown to accumulate in all portions of the plant just prior to bulbing, but after bulbing was initiated the sugar content of the leaves dropped steadily, while that of the bulbs increased.

In field experiments Lloyd and Lewis (59) found nitrogen to be especially beneficial in the production of onion sets when the potassium supplied was adequate, but that nitrogen alone gave only a slight response. Knott (54) found that on muck soils, which had been under cultivation less than ten years, a negative response to fertilizer nitrogen was generally obtained. In sand culture experiments with Ebenezer sets, Wilson (95) showed that excess soil nitrates reduced bulb yields, but had no influence on top growth.

Application of high rates of nitrogen to mother bulbs caused split bulbs and multiple flower scapes, according to Stuart and Griffin (90), while low nitrogen levels were conducive to single scapes and uniformity in time of flowering. High soil nitrogen levels may also induce bulbing instead of flowering.

Stuart and Griffin (90) have described nitrogen deficiency

in Texas 986 Yellow Bermuda onion as being characterized by slow growth, stiff, upright, light-green leaves, the tips of which showed a tendency to die.

Phosphorus

Phosphorus is one of the more important and commonly limiting elements in onion production. Strong et al. (89) reported that response to phosphorus by onions was more pronounced than response to either potassium or nitrogen. Phosphorus deficiency was marked by pale green foliage, slow growth and poor bulb yields. Beaumont et al. (5) and Hawthorne (48) stated that the most pronounced response obtained in their experiments was to phosphorus. On newly cleared muck soils Knott (57) obtained increases in yield with three consecutive annual applications of 192 pounds per acre of P_2O_5 . Scale thickness and color of muck-grown onions was related to phosphorus application according to Knott (56), who observed that the thickest scales were found in the plots treated with the largest amount of phosphorus. Also, it was observed that the effectiveness of copper in improving scale color was associated with adequate phosphorus nutrition.

Bishop (13) found that increasing the quantity of phosphorus applied in the fertilizer increased the phosphorus content of onions.

Stuart and Griffin (90) found that although plants provided no phosphorus during the three-month period prior to bulbing, manifested symptoms of phosphorus deficiency for two of the three months, 93 per cent of the seed produced, germinated satisfactorily. At very low levels of phosphorus, few flower stalks were produced, but seed production per inflorescence was increased.

Potassium

Potassium is frequently low enough in sandy and muck soils to limit yield. Consequently, it is standard practice to apply potassium to these soils either alone or in complete fertilizers.

Beaumont et al. (5) found that potassium fertilizer application was essential for response to phosphorus additions. On newly cleared New York muck soils, Knott (57) obtained increased yields of onions each year with four consecutive annual applications of 195 pounds of K_2O per acre. Campbell (27) presented data showing that under certain conditions potassium tends to reduce injury to onions by sodium. Bremer (20) in Germany found bulb formation in onions to be retarded by a potassium deficiency.

Hawthorne (48) reported potassium to be the least limiting of the three major elements supplied in mixed fertilizers, and after the

first three years potassium applications frequently depressed yields. Campbell (27) likewise found that heavy applications of potassium reduced onion yields particularly when calcium was deficient. High plant potassium concentrations are generally associated with lowered contents of calcium and magnesium (16, 26, 29, 30, 42, 68, 73).

Powers and Wood (70) found a scorching of cane fruit leaves to be associated with excessive manganese absorption where potassium supplies were inadequate. Application of lime and potassium resulted in reduced bronzing of the leaves, increased yields and longer lived plantings. Loehwing (61) discussed the relation of low plant potassium contents to the reduction of sap acidity and decreased solubility of iron in the plant. Nemec (68), Sideris (81) and Shear et al. (79) reported potassium and manganese concentrations to vary conversely in plants.

Sulfur

Sulfur is partly effective through its influence on soil micro-organisms according to Boullanger (18). In a series of trials various vegetables including onions were grown in both sterilized and unsterilized soils to which 70 grams of sulfur per 30 kg. of soil were added. In unsterilized soils sulfur increased the yield in every case, while very little response was encountered in the sterilized soil.

Sulfur by increasing the acidity of soils, increases the availability of iron and manganese (46, 57).

Sulfur is required not only for the amino acids essential in plant metabolism and growth, but, in the onion and similar liliaceous species, sulfur as allyl propyl disulfide, is contained in the essential oils which impart the characteristic flavor and odor of this plant group.

Manganese

Bertrand (9) believed manganese and other micronutrients augmented soil fertility by their catalytic action, and presented data showing their distribution in plants. He maintained that manganese was essential to the oxidizing enzymes of plants. Bishop (14) noted that manganese tended to become localized in regions of active chemical change, and that it is related to chlorophyll formation, and hence to carbon assimilation. Improvement in plant growth and yield of crops as a result of manganese application have been reported by many investigators (35, 39, 44, 46, 50, 51, 57, 69, 80). Harmer (46) has shown that soil reaction governs manganese availability through its influence on the oxidation status of the nutrient. Manganese in the soil may be of value to crop plants by increasing ammonification and nitrification (22) and nitrate assimilation (52).

The relation of manganese to iron in plant metabolism has been the subject of many papers. Rippel (75), Sideris (84), Erkama (38), Pugliese (71), Twyman (93), and Somers and Shive (85), produced and discussed the evidence indicating that an excessive concentration of manganese in the plant is related to reduced utilization or mobility of iron and to symptoms of iron deficiency.

Several investigators (4, 60, 66, 67, 83) have shown increased manganese concentrations in plants as a result of manganese application. Daniel (36) found manganese concentration in peach leaves to be increased by application of a complete fertilizer, by nitrogen and phosphorus, nitrogen and potassium, and to a lesser extent by nitrogen applications. Hopkins and Gourley (49) obtained the same results with apple fruits. Muckenhiern (67) found manganese applications increased bulb yields, manganese contents in the leaves and earlier maturity of onion bulbs.

Eisenmenger and Holland (37) have stated that there is ample evidence that manganese applications tend to increase the concentration of phosphorus in plants.

Iron

Boullanger (19) in classifying the catalytic fertilizers for various crops included iron and sulfur as being especially beneficial to

1. The first

2. The second

3. The third

4. The fourth

5. The fifth

6. The sixth

7. The seventh

8. The eighth

9. The ninth

10. The tenth

11. The eleventh

12. The twelfth

13. The thirteenth

14. The fourteenth

15. The fifteenth

16. The sixteenth

17. The seventeenth

18. The eighteenth

19. The nineteenth

20. The twentieth

21. The twenty-first

onions. Pugliese (71) noted that in solution cultures of wheat the plants were damaged by manganese nitrate in the absence of iron, but that when iron was supplied as the sulfate, a stimulatory action was observed. He concluded that in the presence of adequate iron, plants could tolerate much higher concentrations of manganese than when it was absent. The work of Somers, Gilbert and Shive (86) showed that for normal growth of the soybean in solution culture, the ratio of available iron to manganese should be about 2.0. If the ratio was less than 1.5, symptoms of iron deficiency appeared, and when greater than 2.0, symptoms of manganese deficiency appeared.

Somers and Shive (85) concluded that iron is functional in the ferrous state and that manganese in the plant has a greater oxidizing power than iron. On this basis, ferric iron absorbed by plants is reduced to the ferrous state unless the manganese concentration is such as to prevent the reduction. Since the ferrous iron in any appreciable concentration is considered to be toxic to plants, a deficiency of manganese results in iron toxicity, and these authors suggest that the two conditions, iron toxicity and manganese deficiency, are identical in cause and effect.

Erkama (38) proposed that copper, iron and manganese are a physiological unit, and presented a concept wherein ferrous iron

enters the root cells, and, the manganese concentration permitting, rises through the xylem to the leaves where as reduced iron, it is functional and termed "active iron". This "active iron" becomes incorporated in enzymes and, through the agency of copper, which promotes protein formation, into proteins. Some of the iron may also move back down the plant through the phloem, being incorporated in proteins where copper is functional or deposited as insoluble ferric iron where manganese is active. This scheme allows for the precipitation of iron under conditions of manganese toxicity, and the utilization of iron in the formation of proteins where copper is adequate.

Copper

Felix (41), investigating possible reasons for the poor growth of lettuce and onions on certain muck soils in western New York, obtained a response from both crops by applying 100 to 200 pounds of finely ground CuSO_4 to the soil.

Knott (56) demonstrated that both phosphorus and copper additions to the soil improved color development and increased scale thickness of Yellow Globe Danvers and Ebenezer onions. Copper, in addition to improving the color and scale thickness, gave firmer bulbs.

Muckenhirn (67) applied copper to peat soils in pot experiments and obtained increased top growth of onions.

Lucas (60) obtained an increase in the concentration of copper in the onion as a result of applying copper sulfate to organic soils in which the crop was grown. Miller and Mitchell (66) reported that copper sulfate applied to the soil increased the copper contents of lettuce, but not of spinach.

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EXPERIMENTATION

General Plan

The main objectives of this experiment were to study the influence of eight nutrients (nitrogen, phosphorus, potassium, sulfur, magnesium, copper, manganese and zinc) at three levels each, on the growth of onions, and whether the bulbs so produced would vary in their ability to produce viable seed, or as sets to produce mature marketable bulbs. Relation of composition to performance and yield was to be included in the study. These experiments were begun in the spring of 1952, subsequent to some preliminary work done the previous year, and were to run through the 1953 season when the first portion of the experiment was to be repeated, and the seed and mature bulb crops from the mother bulbs and sets grown in 1952 would be harvested.

GROWTH

1950-51

1951-52

1952-53

1953-54

1954-55

1955-56

1956-57

1957-58

1958-59

1959-60

1960-61

1961-62

1962-63

1963-64

1964-65

1965-66

1966-67

1967-68

1968-69

GROWTH AND COMPOSITION OF THE ONION AS INFLUENCED BY VARIOUS FERTILIZER NUTRIENTS (1952)

This experiment was set up to study the influence of eight nutrients (nitrogen, phosphorus, potassium, sulfur, manganese, copper, magnesium and zinc) at three levels each. on the growth and yield of onions. Downing Yellow Globe was selected as representative of the type which is generally grown to maturity from seed, Ebenezer was selected as the most widely used set onion.

Methods and Materials

Field Procedures:

A series of 20 fertilizer treatments involving combinations of eight nutrients as shown in Table I were employed in a randomized block arrangement with two replications. In addition to these nutrients and the calcium applied as Ca(OH)_2 , iron, as tartrate, and boron, as boric acid, were applied at the rates of 20 and one pound per acre, respectively to each plot. Chlorine, at 5.8 pounds per acre, was applied to each plot by manipulation of the various chemical carriers.

The experimental plots consisted of wooden boxes four feet long, two feet wide and 14 inches deep, filled to a depth of 12 inches with an unproductive sand (Plainfield) into which was incorporated to a depth of four inches one surface inch of screened muck soil, excepting for treatment 20, which was a 1:1 mixture by volume of screened garden soil and muck soil.

==

TABLE I
OUTLINE OF NUTRIENT TREATMENTS

Description *	
1/3 X level of all nutrients (1)	
X level of all nutrients (2)	
3 X level of all nutrients (3)	
1/3 X N (4)	3 X N (5)
1/3 X P (6)	3 X P (7)
1/3 X K (8)	3 X K (9)
0 S (10)	3 X S (11)
0 Mg (12)	3 X Mg (13)
0 Cu (14)	3 X Cu (15)
0 Mn (16)	3 X Mn (17)
0 Zn (18)	3 X Zn (19)
X level of all nutrients in soil-muck mixture (20)	
In treatments 4-19 inclusive all nutrients other than the one listed were at the medium or X level.	
Medium (X) Level of Nutrients in Pounds per Acre	
Nitrogen 150	Magnesium 30
Phosphorus 44	Copper 3
Potassium 83	Manganese 10
Sulphur 50	Zinc 3
Nutrient Carriers	
The following C. P. grade chemicals were used in preparing the nutrient treatment solutions.	
NH ₄ NO ₃	H ₃ PO ₄
(NH ₄) ₂ SO ₄	K ₂ SO ₄
NH ₄ CL	KCL
KNO ₃	MgCl ₂ .6H ₂ O
Mg(NO ₃) ₂ .6H ₂ O	MgSO ₄ .7H ₂ O
Mn(NO ₃) ₂ .6H ₂ O	Zn(NO ₃) ₂ .6H ₂ O
Cu(NO ₃) ₂ .3H ₂ O	

* Numbers in parenthesis following the treatment descriptions correspond to those used in designating the soil determination values in Table XIa.

Part 1

Part 2

Part 3

Part 4

Part 5

Part 6

Part 7

Part 8

Part 9

Part 10

Part 11

Part 12

Part 13

Part 14

Part 15

Part 16

Part 17

Part 18

Part 19

Part 20

Part 21

Part 22

Part 23

Part 24

Part 25

Prior to seeding an application of 83.4 grams, equivalent to 1.000 pounds per acre, of chemically pure hydrated lime was incorporated in the surface four inches of each plot.

The fertilizer application for the entire season was divided into bi-weekly applications, the aim being to have approximately 70 per cent of the total fertilizer applied by the time bulbing had begun. Deionized water was used for irrigation and for bringing the nutrient solutions to equal volume at time of application.

Two varieties of yellow onions, Downing Yellow Globe and Ebenezer, were seeded in rows, as shown in Figure 1, on May 13, 1952. Owing to very extensive damage by maggots, all plots were reseeded June 12. Plants of the Downing variety were thinned to stand approximately two inches apart in the row, while the Ebenezer was seeded thickly for the production of sets, and thinned only where necessary to secure a uniform stand.

In this design the control treatment is the X level of all nutrients (treatment 2), and it also serves as the medium or X level of each nutrient variable. Thus, comparison of the results of treatments 4, 2 and 5 measures the effects of three levels of nitrogen with a uniform nutrient background, whereas the effect of change in background, essentially the N x background interaction, is measured by comparison of treatments 1, 4, 5 and 3. Observation of the various single nutrient effects suggests which of them may be functioning to provide the interaction effects.

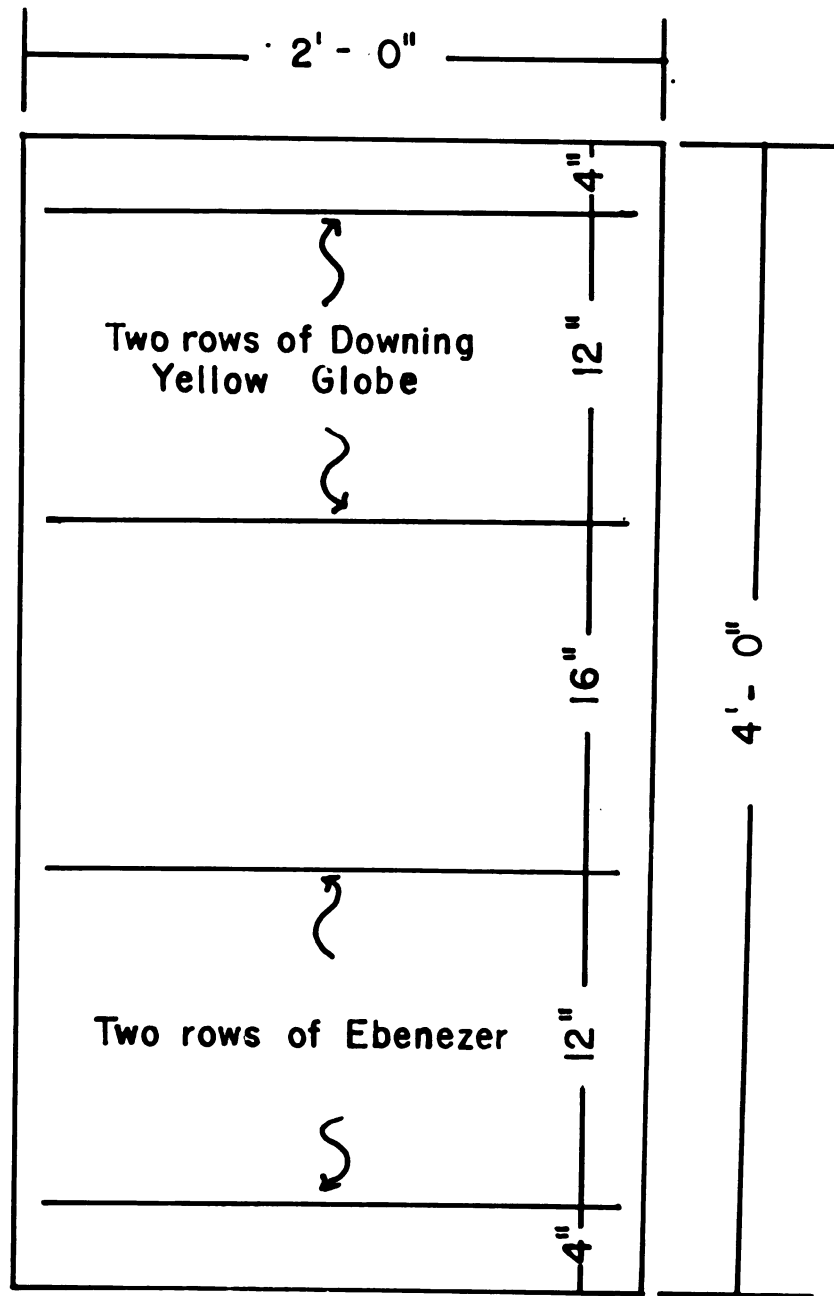


Figure 1. Sample of single plot showing row spacing and arrangement.

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The plants were harvested September 5th before the tops had begun to die, the tops and bulbs being separated at harvest, by cutting the tops off approximately one inch above the bulb. After being weighed a brushed 100 grams aliquot was cut into 2-4 inch lengths and dried at 70 degrees Centigrade. After harvesting the bulbs were placed in partial shade for a few days, then moved into a shed where curing was completed. After curing, the bulbs of each plot were graded into marketable and unmarketable lots, and the weights of each recorded. Marketable Downing bulbs were those 1 1/2 inches or greater in least diameter. Marketable Ebenezer sets were those greater than one-half inch in least diameter.

Laboratory Procedures:

A. Plant Analysis Methods.

The dried material was ground in a Wiley mill to pass a 20-mesh screen, again dried at 70 degrees C for 24 hours, and duplicate 0.5 gram samples were ashed in porcelain crucibles at approximately 550 degrees C. The ashed samples were wetted with one per cent HClO_4 , neutralized with 1:3 70 per cent $\text{HClO}_4:\text{H}_2\text{O}$ by volume, and the crucibles filled to within one-fourth inch of the top with one per cent HClO_4 . The crucibles were then placed on a steam bath until the solution volume was reduced approximately one-half, then filtered while hot through Whatman #40 ashless

paper. The solutions were brought to volume and stored in sample bottles for analysis.

For calcium, potassium, and magnesium the Beckman model DU flame photometer was used, following a modification of the procedure outlined by Brown et al. (21) with hydrogen used as fuel. The operating conditions employed in the photometric determinations are listed in Table II. The standards for potassium contained potassium alone as the perchlorate. Preliminary investigations into the subject of the interferences encountered in flame photometry led to the adoption of the practice of first determining all the elements listed in all samples using reference standards containing only the element concerned as perchlorates in solution. Then, to compensate for the variation introduced into the determination of any particular element by the presence of all possible combinations and levels of the other three elements involved, combination standards were analyzed photometrically and corrections were made for interfering levels of the other elements as they occurred. The evidence found in the course of this preliminary work indicates that the method as outlined by Brown et al. may introduce considerable error into photometric determinations. The method adopted in the work being reported here is believed to render more accurate determinations for calcium and especially for magnesium, since the interferences occurring

TABLE II

OPERATING CONDITIONS EMPLOYED IN THE PHOTOMETRIC DETERMINATIONS

	Potassium	Calcium	Magnesium	Sodium
Wave length μ	771.5	622	371	589
Phototube	Red	Red	Blue	Blue
Load resistance in megohms	10	10	10	10
Slit width mm	.035	.430	.360	.15
Standard conc. ppm which = 100% T	500	400	400	100
Nominal fuel pressure psi	7.3	5.85	7.5	5.4
Oxygen pressure psi	10.0	10.0	12.0	10.0
Sensitivity	5 clockwise	5 clockwise	maximum	midpoint
Selector	.1	.1	.1	.1

1950

1951

1952

1953

1954

1955

1956

1957

1958

1959

1960

1961

1962

1963

1964

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1966

1967

1968

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1974

1975

under specific operating conditions are evaluated.

No interference of practical importance due to sodium in the amounts found in the plants and under the operating conditions employed in the spectro-photometric determination of potassium was encountered. Likewise, in the determination of sodium neither potassium nor calcium seriously interfered under the operating conditions employed. Neither sodium nor magnesium interfered appreciably with the determination of calcium, but potassium did interfere, especially at low concentrations of calcium as shown in Table III. In the photometric determination of the weak emitter magnesium, potassium, and calcium to a lesser extent, interfered.

It is clear from the data in Table IV that under the operating conditions employed as much as 86 per cent of the apparent magnesium could be attributed to the presence of potassium and calcium in concentrations found to exist in the material being analyzed.

Nitrogen was determined by the Kjeldahl method (2). Phosphorus was determined by the A.O.A.C. (2) colorimetric method involving the formation of molybdenum blue.

B. Statistical Methods.

The experiment was arranged for analysis of the growth and yield data as a split plot design, the fertilizer treatments serving as the main plots, each of which was split for variety, and again for top and

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2 5

TABLE III

THE EFFECTS OF VARIOUS LEVELS OF POTASSIUM ON THE
PHOTOMETRIC DETERMINATION OF CALCIUM

(Each Percent T value is the mean of eight readings)

Concentration of Elements in Ppm as Perchlorates		Percent ¹ T	Apparent ² Ppm of Ca	Difference	Percent Error
Ca	K				
400	500	103.2	415.9	15.9	3.97
	200	102.7	413.9	13.9	3.50
	50	101.9	407.7	7.7	1.92
	0	100.0	400.0	0	0
50	500	14.2	53.0	3.0	6.0
	200	13.9	52.0	2.0	4.0
	50	13.3	51.0	1.0	2.0
	0	13.1	50.0	0	0
10	500	4.0	15.3	5.3	53.0
	200	3.5	14.5	4.5	45.0
	50	3.5	14.5	4.5	45.0
	0	2.5	10.0	0	0

¹Percent transmittance

²Ppm as read from curve constructed from transmittance values
using calcium alone in standard solutions.

Operating conditions:

= 622 mu
= .430 mm
H₂ = 5.86 p.s.i.
O₂ = 10.0 p.s.i.

Phototube - red
Sensitivity - midpoint
Selector - 0.1

三
二
一
四
五
六
七
八
九
十
十一
十二
十三
十四
十五
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二十一
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TABLE IV

THE EFFECTS OF CALCIUM, POTASSIUM AND SODIUM IN THE PHOTO-METRIC DETERMINATION OF MAGNESIUM

Element Concentrations in Ppm as Perchlorates				Percent ¹ T	Apparent Mg Ppm	Percent Error
Mg	Ca	K	Na			
100	150	500	0	65.0	123	23.0
100	150	50	0	57.8	117	17.0
100	50	500	0	64.6	122	22.0
100	50	50	0	56.6	114	14.0
100	0	0	0	54.5	100	0
30	150	500	50	34.6	56	86.6
30	150	500	20	34.2	55	83.4
30	150	50	50	26.0	37	23.3
30	150	50	20	25.5	36	20.0
30	50	500	50	33.4	53	76.6
30	50	500	20	33.4	53	76.6
30	50	50	50	24.5	33	10.0
30	50	50	20	24.5	33	10.0
30	50	50	0	22.8	30	0

¹ Average of two readings - 200 ppm Mg = 100 percent T

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wavelength = 371 mu
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bulb yield in accordance with the methods and reasons given by Goulden (45) and Cochran and Cox (31). The analysis of variance including the calculations of least differences required for significance at two confidence levels for both single factor effects and all appropriate interactions as outlined by Cochran and Cox (31) were completed. The plots were considered as completely randomized blocks, relative to the composition data.

Results:

Growth and Yield of Downing Yellow Globe and Ebenezer Onions as Influenced by Fertilizer Treatment

The influence of phosphorus on leaf and marketable bulb production, Table V, was the most outstanding result of this test. In both varieties the medium and high levels of phosphorus applied resulted in significant increases in marketable bulb yields. However, phosphorus did not significantly increase the leaf growth. In fact, with the Ebenezer variety leaf growth was significantly reduced at the high phosphorus level compared to the low level (Table V).

The leaf growth was significantly increased with both the medium and high levels of the complete nutrient treatment. This effect was not entirely due to nitrogen, apparently, since the leaf growth resulting from the medium and high levels of the complete nutrient

2018-10-10

Treatment

Complete

Metastasis

Enlargement

Duration

Side effects

Quality of life

Cost

Conclusion

TABLE V

GROWTH AND YIELD OF MARKETABLE BULBS OF FIRST CROP OF
ONIONS AS INFLUENCED BY TREATMENT
(Grams of fresh weight per 4 square feet)

Treatment *		Downing Yellow Globe			Ebenezer **		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	229	446	735	193	455	1108
	Bulb	131	391	341	58	223	553
	Total	360	837	1076	251	678	1661
Nitrogen	Leaf	165	446	611	598	455	741
	Bulb	150	391	391	149	223	337
	Total	315	837	1002	747	678	1078
Phosphorus	Leaf	381	446	403	671	455	427
	Bulb	170	391	670	115	223	516
	Total	551	837	1073	786	678	943
Potassium	Leaf	294	446	538	604	455	680
	Bulb	191	391	377	104	223	471
	Total	485	837	915	708	678	1151
Sulphur	Leaf	332	446	412	652	455	793
	Bulb	216	391	323	121	223	222
	Total	548	837	735	772	678	1015
Magnesium	Leaf	389	446	502	592	455	655
	Bulb	267	391	448	168	223	385
	Total	656	837	950	760	678	1040
Copper	Leaf	421	446	334	696	455	689
	Bulb	335	391	255	482	223	300
	Total	756	837	589	1178	678	989
Manganese	Leaf	353	446	391	652	455	634
	Bulb	220	391	311	169	223	245
	Total	573	837	702	821	678	879
Zinc	Leaf	618	446	363	542	455	678
	Bulb	461	391	276	243	223	215
	Total	1079	837	639	785	678	893
Complete soil	Leaf		960			701	
	Bulb		607			706	
	Total		1567			1407	

* All except listed nutrients at medium level

** Ebenezer bulbs greater than 1/2 inch in diameter

Leaves	L.S.D.	.05	264	301
	L.S.D.	.01	361	411
Bulbs	L.S.D.	.05	251	94
	L.S.D.	.01	N.S.	128
Totals	L.S.D.	.05	334	210
	L.S.D.	.01	456	287

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treatment were disproportionately greater than the increases resulting from the application of additional nitrogen alone. This indicates that although phosphorus was most outstanding in affecting bulb yields, other nutrients than nitrogen also were responsible for increasing the leaf growth. All the nutrients applied except zinc and copper increased bulb yields.

Although nitrogen increased bulb yields in both varieties, its effect on leaf growth was most pronounced in Downing Yellow Globe. Both nitrogen and potassium appeared to be effective in increasing bulb production at the high level with Ebenezer, but phosphorus was more effective with the Downing Yellow Globe.

The effects of potassium were similar to those of nitrogen, although it appeared to be more effective in increasing leaf growth in Downing Yellow Globe than in the Ebenezer variety.

The high manganese as contrasted to the low manganese treatment increased bulb growth, but had no appreciable effect on leaf growth. The addition of either copper or zinc resulted in decreased bulb yields and foliage growth, indicating that with the sandy soil used in this experiment, both were toxic at the high level of application.

Differences shown by the two varieties in leaf and bulb growth might have been due in part to spacing. In Table VI the total growth

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TABLE VI

TOTAL GROWTH AND YIELD OF FIRST CROP OF ONIONS AS INFLUENCED
BY TREATMENT

(Grams per 4 square feet - varieties combined)

Treatment		Low	Medium	High	Approximate per- cent change * in yield
Complete	Leaf	211	451	921	336
	Bulb	190	398	487	156
	Total	401	849	1048	250
Nitrogen	Leaf	381	451	676	77
	Bulb	168	398	439	161
	Total	549	849	1115	103
Phosphorus	Leaf	526	451	415	-21
	Bulb	257	398	724	182
	Total	783	849	1139	46
Potassium	Leaf	449	451	609	36
	Bulb	223	398	458	105
	Total	672	849	1067	59
Sulphur	Leaf	492	451	602	22
	Bulb	282	398	347	23
	Total	774	849	949	23
Magnesium	Leaf	491	451	578	18
	Bulb	361	398	541	50
	Total	852	849	1119	32
Copper	Leaf	558	451	512	-8
	Bulb	493	398	397	-20
	Total	1015	849	909	-14
Manganese	Leaf	502	451	513	2
	Bulb	288	398	355	23
	Total	790	849	868	10
Zinc	Leaf	580	451	521	-10
	Bulb	421	398	413	-2
	Total	1001	849	934	-7
Complete soil	Leaf		830		
	Bulb		694		
	Total		1524		

* From low to high level of nutrient applied

	L.S.D. .05	L.S.D. .01
Treatments (within apart)	122	166
Parts (within a treatment)	39	52
Treatments (total)	168	230



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(includes both marketable and unmarketable bulb yields) of the two varieties was averaged. Leaf growth was significantly reduced by the medium and high zinc, copper, and phosphorus treatments, and increased by high nitrogen, potassium, sulfur, magnesium, and the complete treatments at the high level of application.

Composition of Downing Yellow Glove and Ebenezer Onions
as Influenced by Treatment

Nitrogen:- In most instances the increase in nitrogen contents may be attributed to reduced growth and incomplete utilization of absorbed nitrogen. Reduced nitrogen concentration as shown in Table VII in most cases was probably a result of increased growth and carbon assimilation. The increase in nitrogen content of the leaves and bulbs of the plants grown with the high nitrogen and high complete treatments suggests that nitrogen absorption and accumulation in these treatments more nearly kept pace with requirements for nitrogen than was true of most of the other treatments. It is obvious that nitrogen was one of the limiting nutritional factors in the growth of the plants. Since there was insufficient plant material for nitrogen determinations for both replications, no estimate of the probability that the values given represent the treatment were possible. The nitrogen content of the bulbs of the Downing variety were roughly half that of leaves, while in the Ebenezer variety

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TABLE VII

NITROGEN CONTENT OF FIRST CROP OF ONIONS AS INFLUENCED BY
TREATMENT
(Nitrogen in per cent of the oven dry weight)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	1.53	1.78	2.02	1.98	2.19	2.91
	Bulb	.84	.80	1.54	1.56	1.92	2.36
Nitrogen	Leaf	1.52	1.78	1.90	1.70	2.19	2.75
	Bulb	.81	.80	1.11	.91	1.92	2.51
Phosphorus	Leaf	1.78	1.78	1.53	2.49	2.19	2.26
	Bulb	1.04	.80	.80	2.44	1.92	2.25
Potassium	Leaf	1.77	1.78	1.49	2.39	2.19	2.25
	Bulb	.96	.80	.78	1.76	1.92	2.60
Sulphur	Leaf	1.81	1.78	1.73	2.35	2.19	2.47
	Bulb	.96	.80	.90	1.62	1.92	1.24
Magnesium	Leaf	1.63	1.78	1.74	2.26	2.19	2.23
	Bulb	.84	.80	.94	2.08	1.92	2.15
Copper	Leaf	1.63	1.78	1.66	2.44	2.19	2.25
	Bulb	.91	.80	.91	1.63	1.92	1.98
Zinc	Leaf	1.84	1.78	1.70	2.36	2.19	2.25
	Bulb	1.15	.80	.97	2.12	1.92	2.85
Complete soil	Leaf		3.06			2.04	
	Bulb		2.20			2.51	

the nitrogen content of tops and bulbs were almost equal .

Phosphorus:- Phosphorus fertilization increased the phosphorus contents of the leaves and bulbs of the Downing variety and the bulbs of the Ebenezer variety, but had little influence on the concentration of phosphorus in the leaves of the latter variety. Increasing the application of nitrogen, as shown in Table VIII, reduced the phosphorus contents of the leaves and bulbs of Downing, possibly as a result of increased growth. With the Ebenezer variety, nitrogen had no effect on leaf contents of phosphorus, but resulted in increasing the phosphorus content of the bulbs .

Potassium, sulfur, and magnesium fertilization had no distinct influence on the phosphorus contents of the leaves or the bulbs of either variety. The addition of copper reduced the leaf content of phosphorus slightly, but had no effect on the bulb content . Manganese showed a tendency to reduce the phosphorus contents of Downing bulbs and Ebenezer leaves, to increase the content of Ebenezer sets, and to have no effect on Downing leaves. Zinc additions, possibly as a result of reducing growth, showed a tendency to increase phosphorus contents of the bulbs of both varieties and the leaves of Ebenezer . As with the nitrogen values, however, statistical analysis could not be applied to this data due to lack of material .

Potassium:- The potassium contents of the leaves of both varieties were increased to a greater extent than were the contents of the

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TABLE VIII

PHOSPHORUS CONTENTS OF FIRST CROP OF ONIONS AS INFLUENCED BY
TREATMENT
(Phosphorus in percent on the oven dry basis)

Treatment*		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	.259	.217	.185	.380	.274	.254
	Bulb	.244	.195	.289	.300	.313	.348
Nitrogen	Leaf	.255	.217	.179	.292	.274	.290
	Bulb	.265	.195	.169	.165	.313	.280
Phosphorus	Leaf	.205	.217	.256	.290	.274	.270
	Bulb	.200	.195	.220	.240	.313	.325
Potassium	Leaf	.228	.217	.242	.282	.274	.226
	Bulb	.195	.195	.216	.266	.313	.154
Sulphur	Leaf	.256	.217	.240	.216	.274	.258
	Bulb	.224	.195	.207	.267	.313	.214
Magnesium	Leaf	.205	.217	.225	.276	.274	.292
	Bulb	.206	.195	.180	.253	.313	.290
Copper	Leaf	.260	.217	.205	.294	.274	.288
	Bulb	.188	.195	.179	.310	.313	.280
Manganese	Leaf	.190	.217	.217	.270	.274	.222
	Bulb	.229	.195	.174	.230	.313	.280
Zinc	Leaf	.170	.217	.210	.284	.274	.284
	Bulb	.190	.195	.200	.280	.313	.250
Complete soil	Leaf		.132			.258	
	Bulb		.379			.500	

* All except listed nutrients at medium level

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bulbs, as a result of potassium application, as shown in Table IX. The reduction in potassium in the Downing variety as a result of increased nitrogen application, was probably the result of dilution by growth. Sulfur showed a tendency to reduce potassium contents in the Downing variety, while magnesium increased it in the leaves of Ebenezer. Copper, manganese, and zinc had no distinct effect on potassium contents. The relatively high potassium content with the low level complete nutrient treatment may be explained by the limited growth resulting from the lack of adequate nitrogen, while the increased contents at the high level complete treatment may be explained as a function of the increase in potassium supplied. The soil plot evidently supplied sufficient potassium, for the levels in leaves and bulbs of both varieties were almost twice those found in the plants from any other plot in spite of high yields and maximum growth.

Magnesium:- The application of magnesium increased the magnesium content of Ebenezer leaves, but had no consistent effect in the other variety, as shown in Table X. Nitrogen applications increased the leaf content of magnesium in both varieties. Phosphorus, sulphur, manganese, copper, and zinc had no consistent influence on the magnesium content of the plants, and potassium reduced it only slightly. The increase in magnesium contents with the high levels of the complete nutrient treat-

TABLE IX

POTASSIUM CONTENT OF FIRST CROP OF ONIONS AS INFLUENCED BY
TREATMENT

(Potassium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	1.46	1.05	1.58	1.74	1.07	1.87
	Bulb	1.36	1.11	1.49	1.34	1.48	1.84
Nitrogen	Leaf	1.59	1.05	.90	1.17	1.07	.98
	Bulb	1.86	1.11	1.05	1.13	1.48	1.33
Phosphorus	Leaf	1.40	1.05	1.16	1.07	1.07	1.31
	Bulb	1.49	1.11	1.39	1.31	1.48	1.29
Potassium	Leaf	.65	1.05	1.18	.65	1.07	1.70
	Bulb	1.19	1.11	1.36	1.10	1.48	1.69
Sulphur	Leaf	1.27	1.05	.76	.96	1.07	1.12
	Bulb	1.33	1.11	.83	1.12	1.48	.91
Magnesium	Leaf	1.15	1.05	1.19	1.01	1.07	1.24
	Bulb	1.19	1.11	1.29	1.30	1.48	1.47
Copper	Leaf	1.20	1.05	1.11	.85	1.07	1.08
	Bulb	1.37	1.11	1.05	1.26	1.48	1.48
Manganese	Leaf	1.13	1.05	1.14	1.15	1.07	1.17
	Bulb	1.11	1.11	1.07	1.07	1.48	1.27
Zinc	Leaf	1.11	1.05	1.23	1.26	1.07	1.25
	Bulb	1.12	1.11	1.29	1.31	1.48	1.48
Complete soil	Leaf		2.74			2.77	
	Bulb		2.17			2.06	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.40	.48
	L.S.D.	.01	.54	.66
Bulbs	L.S.D.	.05	.43	.32
	L.S.D.	.01	.59	.44

TABLE X

MAGNESIUM CONTENT OF FIRST CROP OF ONIONS AS INFLUENCED BY
TREATMENT
(Magnesium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	.086	.100	.111	.123	.088	.135
	Bulb	.050	.056	.047	.047	.058	.070
Nitrogen	Leaf	.093	.100	.123	.084	.088	.148
	Bulb	.050	.056	.061	.058	.058	.058
Phosphorus	Leaf	.085	.100	.090	.084	.088	.078
	Bulb	.053	.056	.038	.056	.058	.062
Potassium	Leaf	.115	.100	.090	.138	.088	.123
	Bulb	.073	.056	.054	.065	.058	.060
Sulphur	Leaf	.115	.100	.090	.133	.088	.133
	Bulb	.059	.056	.056	.048	.058	.038
Magnesium	Leaf	.084	.100	.092	.084	.088	.120
	Bulb	.055	.056	.041	.065	.058	.070
Copper	Leaf	.109	.100	.088	.084	.088	.101
	Bulb	.051	.056	.060	.047	.058	.070
Manganese	Leaf	.110	.100	.084	.133	.088	.099
	Bulb	.068	.056	.039	.048	.058	.070
Zinc	Leaf	.086	.100	.072	.138	.088	.100
	Bulb	.068	.056	.039	.047	.058	.074
Complete soil	Leaf		.206			.107	
	Bulb		.066			.068	

* All except listed nutrients at medium level

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ment may have been a function of the nitrogen applied. These results were not treated statistically and no estimate of error is given.

Calcium:- Compared to the medium level of application, nitrogen at the high level increased the calcium contents in the bulbs of Downing Yellow Globe and in the leaves of Ebenezer as shown in Table XI. Phosphorus applications progressively decreased the calcium content of the bulbs, possibly as a result of increased growth. Increasing the quantities of potassium applied resulted in reduced calcium contents in both varieties. It appeared that magnesium application tended to increase calcium content in the leaves of both varieties. Sulfur, copper and manganese manifested no significant effects with respect to calcium content of the plants, but zinc at the high rate of application showed a tendency to reduce calcium contents in both leaves and bulbs.

YIELD AND PER CENT DOUBLE BULBS OF EBENEZER ONIONS FROM SETS GROWN WITH VARIOUS NUTRIENT TREATMENTS

Methods and Materials

Sets of the Ebenezer variety produced in 1952 in the plots receiving the various nutrient treatments described in the first experiment were stored at 32 degrees Fahrenheit, and planted the following

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2000

2000

2000

2000

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2000

2000

TABLE XI

CALCIUM CONTENT OF FIRST CROP OF ONIONS AS INFLUENCED BY
TREATMENT

(Calcium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	.37	.49	.38	.70	.54	1.00
	Bulb	.43	.41	.42	.20	.17	.18
Nitrogen	Leaf	.61	.49	.55	.52	.54	.78
	Bulb	.34	.41	.52	.25	.17	.16
Phosphorus	Leaf	.38	.49	.45	.49	.54	.52
	Bulb	.49	.41	.33	.19	.17	.15
Potassium	Leaf	.53	.49	.37	.64	.54	.57
	Bulb	.50	.41	.37	.19	.17	.19
Sulphur	Leaf	.48	.49	.50	.68	.54	.63
	Bulb	.48	.41	.47	.21	.17	.19
Magnesium	Leaf	.37	.49	.45	.53	.54	.65
	Bulb	.42	.41	.37	.16	.17	.14
Copper	Leaf	.44	.49	.48	.66	.54	.56
	Bulb	.43	.41	.47	.17	.17	.13
Manganese	Leaf	.46	.49	.43	.62	.54	.56
	Bulb	.45	.41	.32	.16	.17	.18
Zinc	Leaf	.47	.49	.36	.64	.54	.48
	Bulb	.42	.41	.34	.15	.17	.16
Complete soil	Leaf		1.05			.75	
	Bulb		.44			.12	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.19		.05
	L.S.D.	.01	.25		.08
Bulbs	L.S.D.	.05	.08		N.S.
	L.S.D.	.01	.11		N.S.

spring in a muck soil which had been uniformly fertilized with 1,000 pounds per acre of a 3-12-12 mixture applied broadcast. The sets were planted April 8, 1953 three inches apart in rows 16 inches apart. Two sizes of sets, 1/2 to 3/4 inches and 3/4 to 1 inch in least diameter were employed.

A split plot design in which the block (replication) was split for size of set, the subplots being the various nutrient treatments, was used. Three blocks were used, giving three replications for size of set and six replications for nutrient treatment. The subplots consisted of ten plants each, and appropriate border rows were provided.

In September the bulbs were harvested. A record of individual bulb weights, doubleness, and flowering tendency was made.

Results:

The yields of bulbs from sets grown with the high sulfur and the high manganese treatments were reduced 13.2 and 13.7 per cent respectively from the yields obtained from sets grown with the medium level complete nutrient treatment. No difference in effects due to other nutrient treatments were obtained, nor was there any difference in yield due to size of sets employed. No difference in tendency to bolt was observed.

Possibly as a result of reduced average bulb size, the sets

from the high sulfur and the high manganese treatments produced 33.4 and 39.7 per cent fewer double bulbs respectively than did the sets from the medium complete nutrient treatment. The sets produced with the soil-muck mixture (Treatment 20) gave the highest yield and the greatest per cent of doubles, only 54 per cent of the bulbs on the average in six replications being free of this undesirable feature. The small sets produced 24 per cent doubles, compared to 40 per cent for the large sets.

PRODUCTION AND VIABILITY OF SEED BY DOWNING YELLOW GLOBE MOTHER BULBS GROWN WITH VARIOUS NUTRIENT TREATMENTS

Methods and Materials

Four bulbs of Downing Yellow Globe of approximately equal size from each of the nutrient treatments described in the first experiment were planted in fertile soil in 10-inch pots plunged in greenhouse ground beds. The bulbs were planted in February, and watered with tap water as needed. No fertilizer was applied, since the soil had been fertilized and manured the previous fall. Records were kept of flowering dates, and the yield and germination of the seed produced in each inflorescence. The seeds were threshed by hand and cleaned with a Clipper fanning mill equipped with pans for catching the light seed, which were counted for each inflorescence.

Results:

The data relative to seed production were so inconsistent that no reliable inferences could be drawn from them, but it appeared that any nutrient treatment capable of producing a bulb of adequate size should also be capable of producing a bulb which would produce viable seed if planted in a soil and under conditions which would be employed in practical seed production.

The mean seed weight for all treatments was 4.24 milligrams, and the coefficient of variation was 37.5 per cent. The seed weight means ranged from 3.58 to 5.09 milligrams, the lightest seed being found in the treatment without zinc, and the heaviest seed being produced by the bulbs grown the previous year with the soil-muck mixture (Treatment 20).

Germination percentage varied from 73.2 for the minus sulfur treatment to 100 for four treatments; low level complete, low potassium, high copper, and high manganese.

GROWTH, YIELD AND COMPOSITION OF DOWNING YELLOW GLOBE AND EBENEZER ONIONS AS INFLUENCED BY NUTRIENT TREATMENT (1953)

Methods and Materials

A. Field Procedures .

With modifications, this experiment was a repetition of the

first experiment. The same field plot was used both years for each of the various nutrient treatments.

To provide for a uniform stand of evenly spaced plants, a spacing board was used in sowing the Ebenezer seed, and in transplanting the plants of the Downing variety, which had been seeded in vermiculite in the greenhouse and fertilized with a solution of 10-52-17 fertilizer in distilled water. Planting was done in mid-April.

Iron and boron were applied at the rates of four and .20 pounds per acre respectively, instead of the 20 pounds and 1 pound per acre rates used in the first year. Deionized and distilled water were again employed for irrigation and in preparing the nutrient solutions for application.

The plants were harvested the last week in September, and handled as described in the first experiment.

B. Laboratory Procedures.

I. Statistical Methods: - The design employed was a split plot, as described in the first experiment, and the growth and yield data were analyzed in accordance with the design. As before, the growth was measured by the fresh weight of the tops, and the yield was measured by the weight of the cured bulbs.

The composition data were analyzed statistically as completely

randomized blocks, the plants from both replications having been available to permit statistical treatment.

II. Chemical Methods: - In order to learn of the residual effects of the first year's fertilizer applications, prior to planting a soil sample composed of three sub-samples of the complete profile of each plot was collected. The pH of a 1:2 soil:water mixture was determined, using a Beckman pH meter. A five-gram aliquot of soil from each plot was extracted with .135 HCl and the phosphorus and potassium contents of the extract determined. The Beckman model D.U. Flame Photometer was used for the potassium determinations, and the phosphorus was determined by the A.O.A.C. colorimetric method employing hydroquinone and sodium sulfite as reducing agents in complexing ammonium phosphomolybdate (2). The results of these tests are given in Table XIa.

Plant Analyses:

The dried plant material was ground in a Wiley mill to pass a 20-mesh screen, dried again for 24 hours at 70 degrees C, and cooled in a desiccator prior to weighing out samples for analysis.

Nitrogen, potassium, and calcium contents were determined for all plant samples, as described in the first experiment. Sodium was determined by use of the flame photometer following the method pre-

TABLE XIa

INFLUENCE OF TREATMENT ON pH, RESERVE PHOSPHORUS AND
RESERVE POTASSIUM OF THE SOIL*
(All values means of the two replications)

Treatment	pH	Reserve P Lbs. per A.	Reserve K Lbs. per A.
1 1/3 X all	7.56	62	50
2 X all	7.12	81	80
3 3 X all	6.76	117	110
4 1/3 X N	7.52	87	68
5 3 X N	7.09	77	44
6 1/3 X P	7.21	74	64
7 3 X P	7.34	102	63
8 1/3 X K	7.27	75	45
9 3 X K	7.50	89	88
10 O S	7.47	62	57
11 3 X S	6.97	96	60
12 O Mg	7.32	83	81
13 3 X Mg	6.79	97	75
14 O Cu	7.35	60	68
15 3 X Cu	7.19	74	60
16 O Mn	7.40	66	83
17 3 X Mn	7.25	60	71
18 O Zn	7.31	73	66
19 3 X Zn	7.40	67	64
20 X all	7.02	117	401

* Samples taken at the beginning of the second crop season.

viously described for potassium and calcium. Phosphorus, magnesium, manganese, copper, iron and boron were determined spectrometrically with a prism type instrument.

In the spectrometric analyses two-gram samples of oven-dried plant material were ashed at 550 degrees C. The ash was dissolved in 50 per cent (by volume) HCl, LiCl_2 was added as an internal standard, and the solution was brought to a volume of ten milliliters with 50 per cent HCl. A volume of 0.25 milliliters of this solution was applied to each member of three regular carbon electrode pairs. The solution thus applied was rapidly dried under a heat lamp to reduce absorption by the electrode, and the determinations made immediately in a Jarrell-Ash spectrometer. The photographic plates produced were evaluated using a microphotometer, and the logarithm of the relative intensity (relative to the intensity of the lithium line) was plotted against element concentration. The values of four reference samples serving as standards were included on every plate. With few exceptions, the values used in plotting the curves were arithmetical averages of the element concentrations corresponding to the various logarithm of relative intensity values.

Results:

Growth and Yield of Downing Yellow Globe and Ebenezer

Onions as Influenced by Nutrient Treatment

Downing Yellow Globe:- The depression of leaf growth and bulb yields with the high nitrogen treatment was the most pronounced effect obtained in this experiment. As shown in Table XII leaf growth and marketable bulb yield were reduced 44 and 24 per cent respectively in the Downing variety by the high nitrogen compared to the medium nitrogen treatment. This effect of nitrogen was again expressed in the reduction in leaf growth and bulb yield obtained with the high complete compared to the medium complete treatment.

Compared to the low level, application of the high level of either phosphorus or potassium showed a tendency to increase bulb yield, with phosphorus decreasing, and potassium increasing the leaf growth. The high level of magnesium and copper also had a tendency to increase the leaf growth and bulb yield compared to the low level treatments. Sulfur at the high, compared with the medium level of application, resulted in significantly reduced leaf growth, but had no affect on bulb yield. Manganese showed a tendency to increase leaf growth and depress bulb yields at the high level of application, while zinc significantly reduced bulb yields at the high rate of application without affecting leaf growth.

TABLE XII

FOLIAGE GROWTH AND MARKETABLE BULB YIELD OF SECOND CROP OF
ONIONS AS INFLUENCED BY TREATMENT
(Grams of fresh weight per 4 square feet)

Treatments*		Downing Yellow Globe			Ebenezer ¹		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	235	398	204	156	292	212
	Bulb	1097	1195	979	513	682	807
	Total	1332	1593	1183	669	974	1019
Nitrogen	Leaf	322	398	222	220	292	164
	Bulb	1208	1195	911	661	682	567
	Total	1530	1593	1133	881	974	731
Phosphorus	Leaf	317	398	288	244	292	248
	Bulb	1070	1195	1272	611	682	818
	Total	1387	1593	1560	855	974	1066
Potassium	Leaf	230	398	404	202	292	278
	Bulb	1152	1195	1246	787	682	683
	Total	1382	1593	1650	989	974	961
Sulphur	Leaf	315	398	267	231	292	271
	Bulb	1140	1195	1189	621	682	763
	Total	1455	1593	1456	852	974	1034
Magnesium	Leaf	260	398	394	254	292	241
	Bulb	1108	1195	1215	642	682	710
	Total	1368	1593	1609	896	974	951
Copper	Leaf	276	398	398	223	292	295
	Bulb	1195	1195	1294	666	682	781
	Total	1471	1593	1692	889	974	1076
Manganese	Leaf	262	398	339	302	292	342
	Bulb	1111	1195	1077	843	682	806
	Total	1373	1593	1416	1145	974	1148
Zinc	Leaf	309	398	293	221	292	236
	Bulb	1366	1195	1090	809	682	756
	Total	1675	1593	1383	1030	974	992
Complete soil	Leaf		278			198	
	Bulb		1238			903	
	Total		1416			1101	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	109	57
	L.S.D.	.01	149	78
Bulbs	L.S.D.	.05	208	179
	L.S.D.	.01	285	N.S.
Totals	L.S.D.	.05	193	152
	L.S.D.	.01	264	207

In terms of total growth, nitrogen and zinc were significantly detrimental at the high level, while potassium, magnesium and copper were significantly beneficial at the medium level compared to the low level of application as shown in Table XIII.

Ebenezer:- Although, as in the Downing Yellow Globe, nitrogen first increased then reduced leaf growth with increased applications, bulb yields were not significantly reduced (Table XII). The detrimental effect of nitrogen relative to leaf growth was reflected again in the complete treatment. Phosphorus at the high level resulted in increased bulb yield compared to the low level with no effect on leaf growth. It is quite probable that the increased bulb yield obtained with the application of the high level complete treatment was due in part to the added phosphorus applied.

Potassium resulted in a significant increase in leaf growth, perhaps at the expense of set production, when applied at the medium level compared to the low. Copper did not reduce set yields in the second experiment as it did in the first experiment and increase leaf growths.

Varieties Combined:- No pronounced difference in leaf color due to treatment was observed, but in both years the plants grown in the soil-muck plot (Treatment 20) were darker green in color than those in any other plot. The fresh weight data express the size of the

TABLE XIII

FOLIAGE GROWTH AND TOTAL BULB YIELD OF SECOND CROP OF
ONIONS AS INFLUENCED BY TREATMENT
(Mean yields in grams per 4 square feet - varieties combined)

Treatment **		Low	Medium	High	Approximate * Percent Change in Yield
Complete	Leaf	196	345	208	6
	Bulb	872	1009	940	8
	Total	1068	1354	1148	8
Nitrogen	Leaf	271	345	193	-29
	Bulb	966	1009	777	-20
	Total	1238	1354	970	-22
Phosphorus	Leaf	281	345	268	5
	Bulb	921	1009	1093	14
	Total	1202	1354	1361	13
Potassium	Leaf	216	345	340	57
	Bulb	978	1009	994	2
	Total	1194	1354	1334	12
Sulphur	Leaf	273	345	269	-2
	Bulb	934	1009	1029	10
	Total	1207	1354	1298	8
Magnesium	Leaf	257	345	318	24
	Bulb	919	1009	1026	12
	Total	1176	1354	1344	14
Copper	Leaf	249	345	322	29
	Bulb	1000	1009	1098	10
	Total	1249	1354	1420	14
Manganese	Leaf	282	345	341	21
	Bulb	1037	1009	997	-4
	Total	1319	1354	1338	2
Zinc	Leaf	266	345	265	0
	Bulb	1142	1009	990	-13
	Total	1408	1354	1255	-11
Complete soil	Leaf		213		
	Bulb		1100		
	Total		1313		

* From low to high level of nutrient applied

** All except listed nutrients at medium level

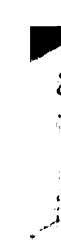
	L.S.D. .05	L.S.D. .01
Leaves	120	N.S.
Bulbs	N.S.	N.S.
Totals	72	99

foliage better than any other measure. No blast occurred, or was there any difference in leaf tip die-back among the treatments.

Averaging the combined growth and yield of the two varieties in 1953 (Table XIII) showed the general tendency of nitrogen and the complete treatment at the high levels of application to reduce leaf and total growth compared with medium level. Phosphorus, potassium, sulfur, magnesium and copper increased the total growth at the medium and high levels of application compared to the low level. Manganese had no significant effect, but zinc at the high level of application reduced total growth.

Leaf:Bulb Ratios and Growth:- The relation of top growth to bulb yield for the two years is shown in Table XIV. The effectiveness of the high level of phosphorus, for example, in increasing the bulb yield relative to the top growth was manifested in the smallest ratios, 0.60 for Downing Yellow Globe, and 0.83 for Ebenezer in the first crop. The averages for the two varieties were 1.43 for Downing Yellow Globe and 2.90 for Ebenezer in 1952, and 0.27 and 0.31 for these varieties in the following year.

Compared to 1952, when they resulted in increased growth, the high levels of nitrogen and potassium were detrimental to growth in 1953. Zinc reduced growth and yield both years. Copper reduced yields the first year, but not the second, while phosphorus and magnesium were beneficial both years. Sulfur has no pronounced detrimental or beneficial



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TABLE XIV
LEAF: BULB RATIOS

Treatment		First Crop			Second Crop		
		Low	Medium	High	Low	Medium	High
Complete	Downing	1.75	1.14	2.15	.23	.33	.21
	Ebenezer	3.33	2.04	2.01	.25	.36	.24
Nitrogen	Downing	1.10	1.14	1.56	.27	.33	.24
	Ebenezer	4.01	2.04	2.20	.31	.36	.26
Phosphorus	Downing	2.24	1.14	0.60	.30	.33	.23
	Ebenezer	5.83	2.04	0.83	.32	.36	.31
Potassium	Downing	1.54	1.14	1.43	.22	.33	.33
	Ebenezer	5.80	2.04	1.44	.28	.36	.40
Sulphur	Downing	1.54	1.14	1.31	.28	.33	.23
	Ebenezer	5.38	2.04	3.57	.38	.36	.32
Magnesium	Downing	1.46	1.14	1.12	.23	.33	.33
	Ebenezer	3.46	2.04	1.70	.35	.36	.28
Copper	Downing	1.26	1.14	1.31	.24	.33	.30
	Ebenezer	1.44	2.04	2.29	.28	.36	.33
Manganese	Downing	1.60	1.14	1.26	.24	.33	.32
	Ebenezer	3.86	2.04	2.59	.32	.36	.37
Zinc	Downing	1.34	1.14	1.31	.23	.33	.27
	Ebenezer	2.23	2.04	3.15	.25	.36	.27
Complete soil	Downing		1.58			.19	
	Ebenezer		0.99			.22	

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effect either year, but appeared to influence leaf growth more than it did bulb yield.

Composition

Nitrogen:- The nitrogen contents of the leaves and bulbs of both varieties were found to be significantly increased by the high rate of nitrogen application. The nitrogen contents of the leaves and the bulbs of the Downing variety were increased 28 and 30 per cent respectively as a result of high level nitrogen application, compared to the low. In the Ebenezer variety application of the high level of nitrogen compared to the low increased the nitrogen contents of the leaves 44 per cent, and of the bulbs 32 per cent. The high level complete nutrient treatment also resulted in significantly increased nitrogen contents in both leaves and bulbs of both varieties, which was due chiefly to the nitrogen supplied, since no other nutrient consistently increased the nitrogen contents of the plant (Table XV). With few exceptions the lowest nitrogen content found in either variety was in those plants grown with the low level complete nutrient treatment. In the soil plot a slight increase in the nitrogen content of the bulb and slightly reduced contents in the leaves were found.

The tendency of the high nitrogen and high complete treatments to promote increased leaf and bulb nitrogen contents was

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TABLE XV

NITROGEN CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED BY
TREATMENT

(Nitrogen in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	2.76	2.97	3.62	3.03	3.31	3.76
	Bulb	1.99	2.40	3.15	2.17	2.63	2.93
Nitrogen	Leaf	2.86	2.97	3.65	2.77	3.31	4.00
	Bulb	2.11	2.40	2.75	2.16	2.63	2.85
Phosphorus	Leaf	3.14	2.97	2.95	3.09	3.31	3.23
	Bulb	2.52	2.40	2.43	2.84	2.63	2.59
Potassium	Leaf	3.10	2.97	3.11	3.40	3.31	3.28
	Bulb	2.72	2.40	2.47	2.85	2.63	2.64
Sulphur	Leaf	2.96	2.97	2.92	3.23	3.31	3.22
	Bulb	2.44	2.40	2.45	2.67	2.63	2.43
Magnesium	Leaf	3.03	2.97	3.05	3.28	3.31	3.34
	Bulb	2.50	2.40	2.69	2.73	2.63	2.91
Copper	Leaf	3.14	2.97	2.92	3.14	3.31	3.19
	Bulb	2.41	2.40	2.49	2.71	2.63	2.81
Manganese	Leaf	2.71	2.97	3.09	3.33	3.31	3.33
	Bulb	2.54	2.40	2.37	2.84	2.63	2.64
Zinc	Leaf	2.85	2.97	2.99	3.25	3.31	3.36
	Bulb	2.41	2.40	2.54	2.64	2.63	2.76
Complete soil	Leaf		2.94			3.04	
	Bulb		2.73			2.79	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.34		.26
	L.S.D.	.01	.46		.36
Bulbs	L.S.D.	.05	.44		.30
	L.S.D.	.01	.60		.40

observed both years, though the nitrogen contents found in the 1953 crops were about 50 per cent greater than those found in the 1952 crops. This may have been due in part, at least, to the fact that about 15 per cent of the annual nitrogen allotment had been applied to the crop destroyed by maggots in 1952, and may not have been completely available to the replants.

On the average, Ebenezer contained approximately eight per cent more nitrogen in the leaves and bulbs than did the Downing Yellow Globe variety.

Phosphorus:- The phosphorus content of the onion bulb was two to eight times greater than that in the leaf, and in this respect differed distinctly from the other nutrients studied. The influence of treatment on the content of phosphorus in the bulb was striking; a difference of 294 per cent being found between the highest and lowest phosphorus contents of the bulbs (Table XVI).

The application of phosphorus resulted in increased phosphorus content of the bulbs of both varieties.

The data for the two years were quite different, the phosphorus content of the 1952 crops being essentially the same for leaf and bulb (Table VIII). The 1953 crops were found to

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TABLE XVI

PHOSPHORUS CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED
BY TREATMENT

(Phosphorus in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	.17	.15	.19	.14	.13	.17
	Bulb	.34	.60	1.24	.59	.75	1.34
Nitrogen	Leaf	.12	.15	.16	.14	.13	.15
	Bulb	.43	.60	.42	.68	.75	.63
Phosphorus	Leaf	.14	.15	.14	.14	.13	.15
	Bulb	.36	.60	.83	.54	.75	1.03
Potassium	Leaf	.14	.15	.14	.18	.13	.14
	Bulb	.42	.60	.53	.63	.75	.77
Sulphur	Leaf	.15	.15	.13	.14	.13	.16
	Bulb	.35	.60	.40	.60	.75	.75
Magnesium	Leaf	.13	.15	.14	.12	.13	.15
	Bulb	.44	.60	.74	.76	.75	.77
Copper	Leaf	.15	.15	.13	.13	.13	.15
	Bulb	.51	.60	.54	.73	.75	.70
Manganese	Leaf	.13	.15	.12	.15	.13	.15
	Bulb	.40	.60	.43	.64	.75	.72
Zinc	Leaf	.16	.15	.14	.15	.13	.14
	Bulb	.37	.60	.56	.60	.75	.62
Complete soil	Leaf		.12			.13	
	Bulb		.53			.89	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.03	N.S.
	L.S.D.	.01	.04	N.S.
Bulbs	L.S.D.	.05	N.S.	.06
	L.S.D.	.01	N.S.	.09

contain about 27 per cent less phosphorus in the leaves and 185 more phosphorus in the bulbs than the 1952 crops in the case of the Downing Yellow Globe variety. However, the content of phosphorus in the bulbs was found to be much more variable than the leaf content in both years.

Potassium: - Potassium influenced its own absorption or accumulation in the plant to a greater extent than was found with any other nutrient, with the exception of the effect of phosphorus on the bulb content. The effect was found in both bulb and leaf potassium contents, but in contrast to phosphorus this response was more pronounced in the leaves. Compared to the low level, the high level of potassium applied increased the leaf content of potassium 181 per cent in Downing leaves. On the same basis nitrogen increased the potassium concentration in the leaves approximately 24 per cent. The potassium contents of the Ebenezer variety were also increased by application of both nitrogen and potassium. None of the other nutrients appeared to have an independent effect on potassium absorption in either variety (Table XVII). However, in combination the other elements apparently influenced potassium accumulation, as evidenced by the high concentrations in both leaf and bulb with the high level complete nutrient treatment. On the average, Ebenezer containly slightly more potassium in both leaves and bulbs than did Downing Yellow Globe. In the 1952 crop (Table IX) the

TABLE XVII

POTASSIUM CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED
BY TREATMENT

(Potassium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	1.38	2.84	5.21	1.90	3.32	4.89
	Bulb	1.10	1.49	2.12	1.22	1.63	2.11
Nitrogen	Leaf	3.27	2.84	4.04	3.26	3.32	4.05
	Bulb	1.66	1.49	1.30	1.62	1.63	1.60
Phosphorus	Leaf	3.18	2.84	3.11	3.54	3.32	3.59
	Bulb	1.57	1.49	1.59	1.68	1.63	1.65
Potassium	Leaf	1.54	2.84	4.33	2.06	3.32	4.25
	Bulb	1.00	1.49	1.90	1.20	1.63	1.97
Sulphur	Leaf	3.00	2.84	2.86	2.96	3.32	3.24
	Bulb	1.44	1.49	1.54	1.67	1.63	1.55
Magnesium	Leaf	3.34	2.84	3.07	3.46	3.32	3.38
	Bulb	1.51	1.49	1.66	1.64	1.63	1.68
Copper	Leaf	3.13	2.84	3.03	3.28	3.32	3.30
	Bulb	1.56	1.49	1.62	1.70	1.63	1.52
Manganese	Leaf	3.25	2.84	2.87	3.21	3.32	3.21
	Bulb	1.49	1.49	1.48	1.69	1.63	1.59
Zinc	Leaf	3.28	2.84	2.84	3.17	3.32	3.39
	Bulb	1.40	1.49	1.60	1.60	1.63	1.60
Complete soil	Leaf		3.46			4.75	
	Bulb		2.00			1.93	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.55		.71
	L.S.D.	.01	.75		.97
Bulbs	L.S.D.	.05	.33		.21
	L.S.D.	.01	.45		.28

bulbs generally contained more potassium than the leaves, but the reverse was found to be true in 1953.

Magnesium: - Potassium application had significantly more influence on the magnesium content of the leaves than did the quantity of magnesium applied (Table XVIII). In both varieties an increase in the quantity of potassium applied resulted in a 50 per cent reduction in the magnesium content of the leaves, which was associated with an increase in leaf potassium content, as shown in Figure 2.

This effect of potassium probably also accounts for the depression in leaf magnesium content with the high level complete nutrient treatment (Table XVIII) and Figure 2. There was an indication that zinc, copper and sulfur reduced leaf magnesium contents. Manganese and magnesium had no effect on the magnesium content in the Downing Yellow Globe variety, but increasing the quantity of magnesium applied significantly increased the magnesium content of the leaves of Ebenezer.

The bulb content of magnesium in both varieties, on the average, was about half that of the leaf. Although the leaf content of magnesium was adversely affected by potassium applications, potassium had relatively little influence on the magnesium content of the bulb. The magnesium contents of leaves and bulbs of both varieties were found to be markedly lower in 1952 than in 1953 (Table X).

TABLE XVIII

MAGNESIUM CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED
BY TREATMENT

(Magnesium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	.53	.38	.33	.65	.49	.45
	Bulb	.17	.20	.20	.20	.23	.22
Nitrogen	Leaf	.37	.38	.39	.45	.49	.53
	Bulb	.18	.20	.16	.23	.23	.23
Phosphorus	Leaf	.39	.38	.42	.50	.49	.55
	Bulb	.16	.20	.21	.21	.23	.25
Potassium	Leaf	.56	.38	.27	.89	.49	.41
	Bulb	.18	.20	.16	.21	.23	.24
Sulphur	Leaf	.51	.38	.36	.51	.49	.57
	Bulb	.16	.20	.18	.24	.23	.27
Magnesium	Leaf	.36	.38	.32	.46	.49	.63
	Bulb	.16	.20	.22	.22	.23	.25
Copper	Leaf	.41	.38	.29	.54	.49	.55
	Bulb	.20	.20	.22	.25	.23	.23
Manganese	Leaf	.39	.38	.36	.54	.49	.54
	Bulb	.18	.20	.20	.21	.23	.19
Zinc	Leaf	.46	.38	.39	.51	.49	.46
	Bulb	.15	.20	.22	.23	.23	.18
Complete soil	Leaf		.31			.39	
	Bulb		.16			.20	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.09	.14
	L.S.D.	.01	.13	.20
Bulbs	L.S.D.	.05	N.S.	N.S.
	L.S.D.	.01	N.S.	N.S.

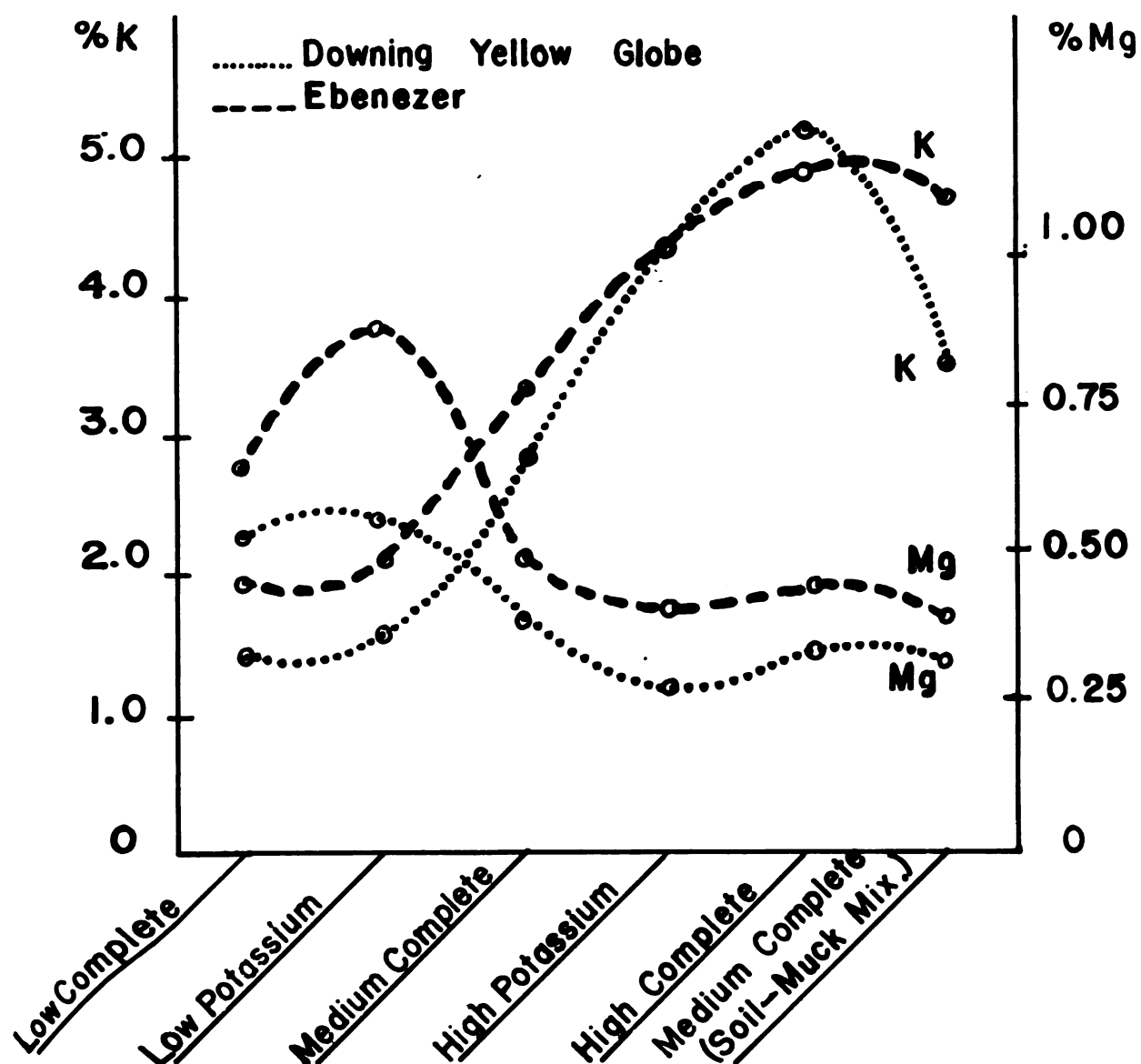


Figure 2. Influence of Potassium Application on the Potassium and Magnesium Contents of the Leaves.

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Manganese: - The quantity of nitrogen supplied in the nutrient treatment resulted in a phenomenal increase in the contents of manganese found in the leaves and bulbs of both varieties. However, manganese did not appear to influence its own absorption. Although no other nutrient, with the exception of sulfur, was found to significantly increase manganese accumulation in either leaf or bulb, in combination they appeared to increase the effectiveness of nitrogen in increasing manganese accumulation (Table XIX). On the average, the leaf content of manganese was about twice that of the bulb content in the Downing Yellow Globe variety, and more than twice the bulb content in the Ebenezer variety.

Calcium: - In Downing Yellow Globe high leaf calcium concentrations were associated with the high level sulfur, the low level potassium and the low level zinc treatments. High nitrogen applications significantly increased and high potassium treatment significantly decreased the calcium content in the leaves (Table XX). In Ebenezer the high levels of applied manganese, copper, sulfur and nitrogen significantly increased the calcium contents of the leaves. The calcium content of the bulbs of Downing Yellow Globe was found to be about 10 per cent of that of the leaves, and in Ebenezer the sets contained only about 6.5 per cent as much calcium as the leaves. On the average, Ebenezer contained more calcium in the leaves and less in the bulbs

TABLE XIX

MANGANESE CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED
BY TREATMENT

(Manganese in ppm on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	24	55	261	39	69	298
	Bulb	17	25	86	19	28	80
Nitrogen	Leaf	29	55	168	49	69	206
	Bulb	18	25	56	25	28	62
Phosphorus	Leaf	49	55	53	48	69	63
	Bulb	26	25	34	26	28	30
Potassium	Leaf	44	55	30	95	69	40
	Bulb	24	25	19	31	28	25
Sulphur	Leaf	44	55	56	43	69	64
	Bulb	22	25	32	24	28	36
Magnesium	Leaf	41	55	26	57	69	50
	Bulb	27	25	25	30	28	25
Copper	Leaf	75	55	42	54	69	63
	Bulb	41	25	35	27	28	29
Manganese	Leaf	51	55	34	64	69	59
	Bulb	30	25	30	27	28	26
Zinc	Leaf	56	55	39	53	69	68
	Bulb	28	25	30	26	28	25
Complete soil	Leaf		31			44	
	Bulb		19			21	

* All except listed nutrients at medium level

Leaves	L.S.D. .05	47	43
	L.S.D. .01	64	58
Bulbs	L.S.D. .05	11	8
	L.S.D. .01	15	11

TABLE XX

CALCIUM CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED
BY TREATMENT

(Calcium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	1.48	1.42	1.59	1.85	2.09	2.18
	Bulb	.18	.15	.15	.13	.12	.13
Nitrogen	Leaf	1.30	1.42	1.74	1.35	2.09	2.50
	Bulb	.16	.15	.18	.13	.12	.17
Phosphorus	Leaf	1.48	1.42	1.79	1.79	2.09	2.03
	Bulb	.20	.15	.16	.14	.12	.11
Potassium	Leaf	2.32	1.42	1.39	2.84	2.09	2.61
	Bulb	.19	.15	.17	.14	.12	.13
Sulphur	Leaf	1.75	1.42	1.91	2.10	2.09	2.72
	Bulb	.21	.15	.14	.13	.12	.14
Magnesium	Leaf	1.69	1.42	1.50	2.04	2.09	2.02
	Bulb	.16	.15	.16	.12	.12	.12
Copper	Leaf	1.68	1.42	1.60	2.09	2.09	2.94
	Bulb	.18	.15	.17	.14	.12	.12
Manganese	Leaf	1.70	1.42	1.64	1.90	2.09	2.95
	Bulb	.16	.15	.16	.14	.12	.13
Zinc	Leaf	1.81	1.42	1.55	1.96	2.09	2.13
	Bulb	.15	.15	.16	.13	.12	.14
Complete soil	Leaf		1.61			2.00	
	Bulb		.14			.13	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.37		.28
	L.S.D.	.01	.50		.38
Bulbs	L.S.D.	.05	N.S.		N.S.
	L.S.D.	.01	N.S.		N.S.

than did Downing Yellow Globe. In the 1952 crop calcium was almost equally distributed in the leaves and bulbs of Downing Yellow Globe, although the variation in content was greater in the leaves than in the bulbs, while in Ebenezer the leaves contained three times as much calcium as the bulbs (Table XI). The leaf content of calcium in both varieties in 1953 was approximately three times the leaf contents found in 1952.

Iron:- In Downing Yellow Globe the high potassium treatment resulted in an increase in the iron contents of the leaves. Nitrogen, also, manifested a tendency to increase iron contents in the leaves, and the high level of the complete nutrient treatment increased the iron contents of the leaves approximately 20 per cent over those found in the high potassium treatment, indicating that some of the other nutrients involved tended to influence iron accumulation, or to increase the effectiveness of potassium in this role (Table XXI). No difference in bulb contents of iron were found which did not fall within the limits of experimental error.

In Ebenezer the highest iron concentration was obtained with the high level of complete nutrient treatment, and the second highest level was obtained with the low potassium treatment, completely reversing the condition encountered with Downing Yellow Globe. However,

TABLE XXI

IRON CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED BY
TREATMENT

(Iron in ppm on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	43	53	106	91	83	109
	Bulb	39	52	63	69	72	76
Nitrogen	Leaf	43	53	74	90	83	105
	Bulb	54	52	57	65	72	80
Phosphorus	Leaf	53	53	53	87	83	95
	Bulb	57	52	50	72	72	68
Potassium	Leaf	43	53	88	104	83	82
	Bulb	51	52	68	73	72	74
Sulphur	Leaf	53	53	48	96	83	98
	Bulb	48	52	51	68	72	72
Magnesium	Leaf	52	53	47	91	83	91
	Bulb	57	52	55	65	72	75
Copper	Leaf	46	53	41	93	83	97
	Bulb	54	52	55	70	72	73
Manganese	Leaf	54	53	46	89	83	90
	Bulb	55	52	54	70	72	73
Zinc	Leaf	64	53	51	89	83	76
	Bulb	50	52	61	69	72	66
Complete soil	Leaf		136			136	
	Bulb		56			81	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	33	N.S.
	L.S.D.	.01	45	N.S.
Bulbs	L.S.D.	.05	N.S.	N.S.
	L.S.D.	.01	N.S.	N.S.

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neither of these differences were statistically significant.

In general, the quantities of iron found in Ebenezer were somewhat higher than those found in the Downing variety.

Boron:- No difference between the boron contents of the bulbs of Downing Yellow Globe due to the various treatments was found. Nitrogen gave a significant increase in the boron content of the leaves when applied alone at the high rate, or in the high level of the complete nutrient treatment (Table XXII). There was a suggestion that zinc and potassium were inimical to increased boron concentrations in the leaves of Downing Yellow Globe.

With Ebenezer no significant differences between either bulb or leaf boron contents due to treatment was found.

With the Downing variety the average bulb content of boron was approximately 71 per cent of the leaf content, but in Ebenezer the bulb content was only 50 per cent of the leaf content.

Sodium:- No consistent difference in the sodium content of the bulbs was found in either Downing Yellow Globe or Ebenezer. In the Downing Yellow Globe variety the sodium contents of the leaves was increased with the low levels of the complete nutrient treatment, the low level of potassium and the low level of nitrogen (Table XXIII). In the Ebenezer variety phosphorus and zinc showed a tendency to lower,

TABLE XXII

BORON CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED BY
TREATMENT

(Boron in ppm on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	25	27	36	42	40	51
	Bulb	17	21	21	21	22	25
Nitrogen	Leaf	28	27	38	39	40	45
	Bulb	21	21	18	23	22	21
Phosphorus	Leaf	32	27	29	40	40	41
	Bulb	23	21	23	21	22	20
Potassium	Leaf	32	27	26	48	40	40
	Bulb	20	21	20	19	22	21
Sulphur	Leaf	31	27	27	46	40	44
	Bulb	18	21	20	20	22	20
Magnesium	Leaf	27	27	26	41	40	45
	Bulb	21	21	22	20	22	21
Copper	Leaf	27	27	25	45	40	49
	Bulb	20	21	20	22	22	20
Manganese	Leaf	27	27	24	48	40	42
	Bulb	20	21	22	21	22	20
Zinc	Leaf	33	27	24	45	40	43
	Bulb	19	21	21	20	22	18
Complete soil	Leaf		20			32	
	Bulb		16			18	

* All except listed nutrients at medium level

Leaves	L.S.D. .05	7	N.S.
	L.S.D. .01	9	N.S.
Bulbs	L.S.D. .05	N.S.	N.S.
	L.S.D. .01	N.S.	N.S.

TABLE XXIII

SODIUM CONTENT OF SECOND CROP OF ONIONS AS INFLUENCED BY
TREATMENT

(Sodium in percent on the oven dry basis)

Treatment *		Downing Yellow Globe			Ebenezer		
		Low	Medium	High	Low	Medium	High
Complete	Leaf	.116	.069	.078	.169	.098	.088
	Bulb	.067	.063	.085	.066	.048	.057
Nitrogen	Leaf	.109	.069	.061	.096	.098	.095
	Bulb	.045	.063	.065	.052	.048	.053
Phosphorus	Leaf	.073	.069	.066	.123	.098	.088
	Bulb	.081	.063	.062	.057	.048	.055
Potassium	Leaf	.136	.069	.034	.126	.098	.074
	Bulb	.081	.063	.056	.058	.048	.055
Sulphur	Leaf	.086	.069	.085	.075	.098	.108
	Bulb	.060	.063	.047	.067	.048	.063
Magnesium	Leaf	.081	.069	.072	.091	.098	.106
	Bulb	.069	.063	.117	.067	.048	.058
Copper	Leaf	.096	.069	.057	.071	.098	.095
	Bulb	.054	.063	.070	.055	.048	.062
Manganese	Leaf	.080	.069	.079	.085	.098	.086
	Bulb	.070	.063	.066	.055	.048	.054
Zinc	Leaf	.081	.069	.056	.130	.098	.088
	Bulb	.065	.063	.057	.056	.048	.053
Complete soil	Leaf		.096			.106	
	Bulb		.080			.059	

* All except listed nutrients at medium level

Leaves	L.S.D.	.05	.044	.054
	L.S.D.	.01	.060	.074
Bulbs	L.S.D.	.05	N.S.	N.S.
	L.S.D.	.01	N.S.	N.S.

and potassium and the high level of the complete nutrient treatment significantly lowered the sodium contents of the leaves.

Although their bulb sodium contents were about the same, the varieties differed in their average leaf contents, the leaves of Ebenezer containing 20 per cent more sodium than the leaves of Downing Yellow Globe.

DISCUSSION

In repeated experiments Downing Yellow Globe and Ebenezer onions were grown in a modified sand culture designed to study the influence of nitrogen, phosphorus, potassium, sulfur, magnesium, copper, manganese, and zinc, at three levels each, on their growth and chemical composition. The relation of these treatments to the production of Downing bulbs and their subsequent performance in the production of viable seed was also studied. The relation of these treatments to the production of Ebenezer sets and their subsequent performance in producing a crop of mature bulbs under field conditions was included in the investigation.

A modified culture of Plainfield sand was employed as a means of obtaining greater precision in the measurement of the effects of the various nutrients, particularly manganese, copper and zinc. A small quantity of organic soil was added to each plot for the purpose of providing a more suitable medium for plant growth, and to obtain the other benefits attending the presence of organic colloids in the cultural media. The spacing of the plants, and the rates of nutrients applied were comparable to those employed in field practice, with the exception of the rate of copper applied, which was reduced because of the pH value of the soil and the lack of any appreciable amount of organic materials

1. The first part of the document is a title page. It contains the title "THE HISTORY OF THE UNITED STATES OF AMERICA" and the author "BY JAMES MADISON".

in the medium. In order to measure single nutrient effects independently, the carrier chemicals were selected to provide variation only in the nutrient being considered as a variable, all others being equal in concentration. This was done because the interpretation of the results of many nutrition experiments have been partially obscured by variation in the nature and concentration of the ions associated with the nutrient variables.

The onion plants were divided into leaf and bulb portions at harvest to facilitate determining the nutrient distribution in the plants. Practically all the onion analysis found in the literature relating to composition have been restricted to the bulb, or to samples of the entire plant included in the sample. The leaf bases of the onion may more nearly correspond to the petioles of dicot leaves which serve as the portion of the plant commonly employed in tissue analysis. Leaf analysis has been suggested as possibly the best index of the nutrient condition of woody dicots (79, 91). The studies reported herein emphasize the difference in the contents of the various nutrients found in both leaves and bulbs. Onion bulbs, though foliar in origin, have been found to behave quite differently than photosynthetically-active portions of the leaves with respect to salt accumulation (8).

The phosphorus content of the onion plant is more equally

distributed between leaves and bulbs when phosphorus is deficient and four to five times more concentrated in the bulb than in the leaf when supplies are adequate, as shown in Table XXIV. Variations in phosphorus content are generally greater in bulbs than in leaves. The nitrogen content of onion bulbs is generally higher, relative to the leaves than the storage organs of beets (6). The relatively high concentration of nitrogen, potassium, calcium, magnesium, and manganese in the leaves compared to the bulbs of onions (Table XXIV) suggests that care be exercised in the selection of the tissue employed in analysis for diagnostic purposes.

Bulb initiation is conditioned by long days and high temperatures, the minimum length of day required to initiate bulbing varying with the variety (62). These factors have been found to modify the response to nutrients. Once the conditions become favorable and bulbing begins, further foliage development becomes much retarded (89); and, since the volume of foliage developed prior to the onset of bulbing is generally related to the size of the bulb subsequently developed, the practice is to fertilize for early leaf growth prior to bulb enlargement. Hawthorne (48) has shown that an excess of nitrogen after bulb development is initiated contributes to thickened necks and poor storage. Excessive nitrogen fertilization also results in an increased number of double and triple growing points and multiple flower scapes. A deficiency of nitrogen

TABLE XXIV

VARIABILITY IN COMPOSITION AND YIELD OF TWO VARIETIES OF ONIONS

	Downing Yellow Globe				Ebenezer			
	Leaf		Bulb		Leaf		Bulb	
	Mean	C*	Mean	C*	Mean	C*	Mean	C*
1952								
Fresh weight (gms)	446	39.9	326	43.6	638	26.9	289	60.9
Nitrogen	1.78	18.6	1.01	32.5	2.29	11.8	2.07	23.9
Phosphorus	.22	15.5	.21	96.8	.28	12.5	.28	25.8
Potassium	1.28	32.34	1.31	22.8	1.27	36.3	1.36	19.8
Calcium	.48	31.2	.42	14.2	.63	19.3	.18	20.9
Magnesium	.20	27.8	.11	17.8	.22	20.7	.12	17.8
1953								
Fresh weight (gms)	300	20.4	1158	9.3	242	19.1	721	14.1
Ash (total gms)	11.70	11.5	5.25	10.2	13.60	13.37	5.28	61.1
Nitrogen	3.03	5.3	2.50	8.4	3.28	3.8	2.68	5.3
Phosphorus	.14	9.9	.63	34.6	.14	15.5	.74	4.1
Potassium	3.17	8.2	1.55	10.1	3.38	10.0	1.64	59.8
Calcium	1.67	10.5	.17	16.1	2.00	6.5	.13	12.6
Magnesium	.39	11.5	.18	22.7	.43	15.7	.22	10.3
Manganese (ppm)	60	37.2	31	17.3	76	26.8	31	12.6
Iron (ppm)	60	25.5	54	22.0	95	26.6	71	12.2
Boron (ppm)	28	11.8	20	10.4	43	18.6	21	12.0
Copper (ppm)	12	34.3	9	23.7	14	22.5	13	16.3
Sodium	.08	28.5	.07	23.3	.10	7.3	.06	8.9

All except those marked ppm are in per cent of the oven dry weight.

*Where data was available all C (coefficient of variation) percentages were based on samples from all replications.

results in rigidly erect, stiff-necked plants whose tops fail to fall over normally. Phosphorus promotes thickened and dark-colored bulb scales, and is necessary for favorable influence of copper (55). The development of full color in pigmented onion's is enhanced by copper, and on acid muck soils additions of copper have been beneficial particularly in conjunction with increased phosphorus fertilization. A marked potassium deficiency results in retarded bulb formation, and in light soils produces thin bulb scales. Excess potash delays maturity of onions grown in muck soils (54). A deficiency of manganese often results in reduced yields and retarded bulb development on organic soils which are alkaline in reaction. The application of sulfur, by increasing soil acidity, increases the availability of manganese, but must be carefully controlled to avoid reduction in the availability of copper, nitrogen and phosphorus (46).

Yield as Influenced by Nutrition

In this study neither the shape nor the color of the bulbs was influenced by the treatments employed. Phosphorus exerted the most pronounced effects of any nutrient the first year, and gave by far the smallest leaf:bulb ratio and highest bulb yield. Comparing the low level with the high level phosphorus treatment, bulb yields were increased

294 and 348 per cent respectively for Downing and Ebenezer. Although the leaf growth of Downing was slightly increased by added phosphorus the leaf growth of Ebenezer was decreased almost 40 per cent. The following year added phosphorus had very little effect on the leaf growth of either variety, but again increased bulb yields. The bulb yield of Ebenezer as a result of the high phosphorus treatment, was increased relatively more than was the bulb yield of Downing.

The favorable effect of added nitrogen the first year may have been due to the extreme deficiency of this element in the sand employed. High levels of the other nutrients, including phosphorus and potassium, as indicated in the yields obtained with the high level complete treatment, failed to offset or counter the effects of high nitrogen in 1953. The high nitrogen application reduced the growth of Downing more than it did the growth of Ebenezer. It appeared that Ebenezer, either as a result of its genetic constitution or closer spacing, was less sensitive to changes in the quantities of nitrogen and phosphorus available than the Downing Yellow Globe.

Potassium applied at the high rate compared with the low in the first crop increased the leaf growth of Downing Yellow Globe 83 per cent and of Ebenezer 13 per cent, with corresponding bulb yield increases of 97 and 352 per cent. The following season the high level of potassium

a gain increased the leaf and bulb growth of the Downing variety 76 and 8 per cent respectively, and while decreasing set production in Ebenezer 13 per cent increased the leaf growth 38 per cent. Potassium, then, seemed to promote both leaf and bulb growth, as did nitrogen, while phosphorus promoted bulb growth at the expense of foliage development. These differences probably account for the delay in maturity accompanying the use of high rates of nitrogen and potassium, and the increase in earliness resulting from increased rates of phosphorus application. These results are in accord with the findings of Strong (89), Beaumont et al. (5), Knott (54), and Hawthorne (48), with the onion, and with the results of Amin (1) relative to the effects of phosphorus on the hyacinth. The results suggest that onions grown for sets, as they tend to be more foliar in development, might be benefitted by a reduced $K_2O:P_2O_5$ ratio than appears to be optimum for the production of mature bulbs. Many of the results of investigations of the effects of phosphorus upon the growth of bulbs have shown reduced top and bulb growth due to high phosphorus levels, but in most of the solution cultures used it was found that the phosphate precipitated certain of the micronutrients, and it is possible that some of the supposedly detrimental effects of phosphorus were indirect and the result of decreased availability of these micronutrients (23). The data of Amin (1) in this connection show almost no

change in phosphorus concentration in the hyacinth bulbs which suffered reduced foliar and bulb growth as a result of high phosphorus concentrations in the nutrient solutions employed.

Increased leaf and bulb growth in both varieties resulted from the high level of magnesium applied in both seasons. Magnesium tended to promote leaf and bulb growth more equally than did some of the other nutrients.

Sulfur at the high rate of application compared with none increased the yield and growth of both varieties both seasons with the exception that the leaf growth of Downing was reduced the second season. Supplied in the sulfate form, sulfur increased the soil acidity from pH 7.49 to pH 6.79.

Adding manganese increased the leaf growth of Downing and decreased the leaf growth of Ebenezer in both seasons. The bulb yield of both varieties were increased the first and slightly decreased the second seasons.

In the first crop both copper and zinc reduced leaf and bulb growth, but in the second year copper applications resulted in slightly increased growth, while zinc at the high level of application reduced bulb yield and total growth 13 and 11 per cent respectively on the basis of an average of both varieties.

This suggests that where nitrogen, phosphorus and potassium are adequate, or in excess, a favorable response to copper may be anticipated. The detrimental effect of zinc was more pronounced on the Downing than on the Ebenezer variety, but it was not possible to ascertain whether this was a differential varietal response, or whether it was associated with bulb enlargement.

The data relative to seed production by Downing mother bulbs produced the previous season with the various nutrient treatments was incomplete, since many of the bulbs failed to produce flowers. It is doubtful if the nutrients provided the mother bulb during its formation have any great effect on the resulting seed crop, providing the mother bulb is of normal size and is planted in adequately fertilized soil. However, high nitrogen applications have been shown to induce multiple inflorescences which frequently increased seed yield. Stuart and Griffin (90) have shown that even where no phosphorus was applied to the mother bulb for three months prior to flowering, germinability of the seed produced was not affected.

No differential effect on the keeping quality or tendency to sprout in storage due to treatment was found in either variety, or in the bulbs of Ebenezer grown from sets that were produced under the various treatments. Sixty Ebenezer sets produced in 1952 with 15 of the 20

nutrient combinations employed were planted in a replicated experiment on muck soil. Although the Ebenezer sets grown with the high sulfur and the high manganese treatments resulted in reduced yields in the crop grown from them the following year, possibly owing to smaller average bulb size, significantly fewer double bulbs were obtained, tending to offset the importance of the reduction in yield. It appeared that plants in the same soil and provided normal fertilization, sets of the same size have equal productive capacity.

The Influence of Treatment on Plant Composition

Nitrogen:- The high rate of applied nitrogen increased the nitrogen contents of the bulbs and leaves despite greatly increased yields the first season resulting in a 214 per cent increase in the nitrogen removed by the bulbs of Downing, and a 484 per cent increase in the nitrogen removed by the sets of Ebenezer. In the next year in spite of higher yields with the low nitrogen treatment, the nitrogen removed in the bulbs with the high nitrogen treatment was increased over the preceding year, with the high application, due to an increased nitrogen content of the crop, indicating luxury consumption. Thus, with a 25 per cent decrease in yield, the removal of nitrogen in the bulbs of Downing was slightly increased.

Alteration of the quantity of applied nitrogen influenced the

concentration of the other nutrients in the tissues. The potassium concentration of the leaves of both varieties was increased about 25 per cent. and the calcium concentration increased approximately 34 per cent in Downing, and 85 per cent in Ebenezer leaves, by the high as compared with the low level of applied nitrogen. In the bulb of the Downing variety, potassium content was reduced by the high nitrogen treatment. No pronounced influence of nitrogen application on the calcium content of the bulbs of either variety was found. No significant change in the bulb or leaf content of magnesium, sodium, phosphorus, or copper was found to be associated with increasing rates of nitrogen application.

However, a phenomenal increase in the concentration of manganese and an increase in the concentration of iron in the leaves and bulbs of both varieties resulted from increasing the level of nitrogen applied from the low to the high level.

It is improbable that the increased soil acidity resulting from the high nitrogen treatment was responsible for the increased manganese concentration in the plants, because the high sulfur treatment reduced the soil pH more than did the high nitrogen treatment, but the plants contained less than one-third as much manganese.

Although the high sulfate sulfur treatment increased the manganese content of the leaves 40 per cent over the low treatment,

the high nitrogen treatment, as compared to the low, increased the manganese contents of Downing and Ebenezer leaves 480 and 320 per cent respectively. The bulb contents were also increased as shown in Table XIX, and were about equal to the manganese contents found in cherry and peach leaves as reported by Kenworthy (53), while the levels found in the onion leaves were more than twice as great. Of several plants studied, True (92) found spinach to be the only plant with a higher manganese content in the root than in the leaf. Though none of the other nutrients individually showed any tendency to increase the manganese contents of the leaves or bulbs at high rates of application, when their application was associated with the high application of nitrogen in the high complete treatment, the leaves accumulated approximately an additional 100 ppm of manganese. On the basis of this evidence, it appears that it is quite possible that the extremely high manganese contents in the leaves and bulbs of the 1953 crop were toxic to the extent of being responsible for the reduced yields obtained with the high rates of nitrogen applied.

The relation of nitrogen application to nitrogen, manganese and iron concentrations in the leaves and the yields of Downing and Ebenezer bulbs are shown graphically in Figures 3 and 4. These diagrams illustrate the slight change in nitrogen and iron content accom-

Figure 3. Downing Yellow Globe

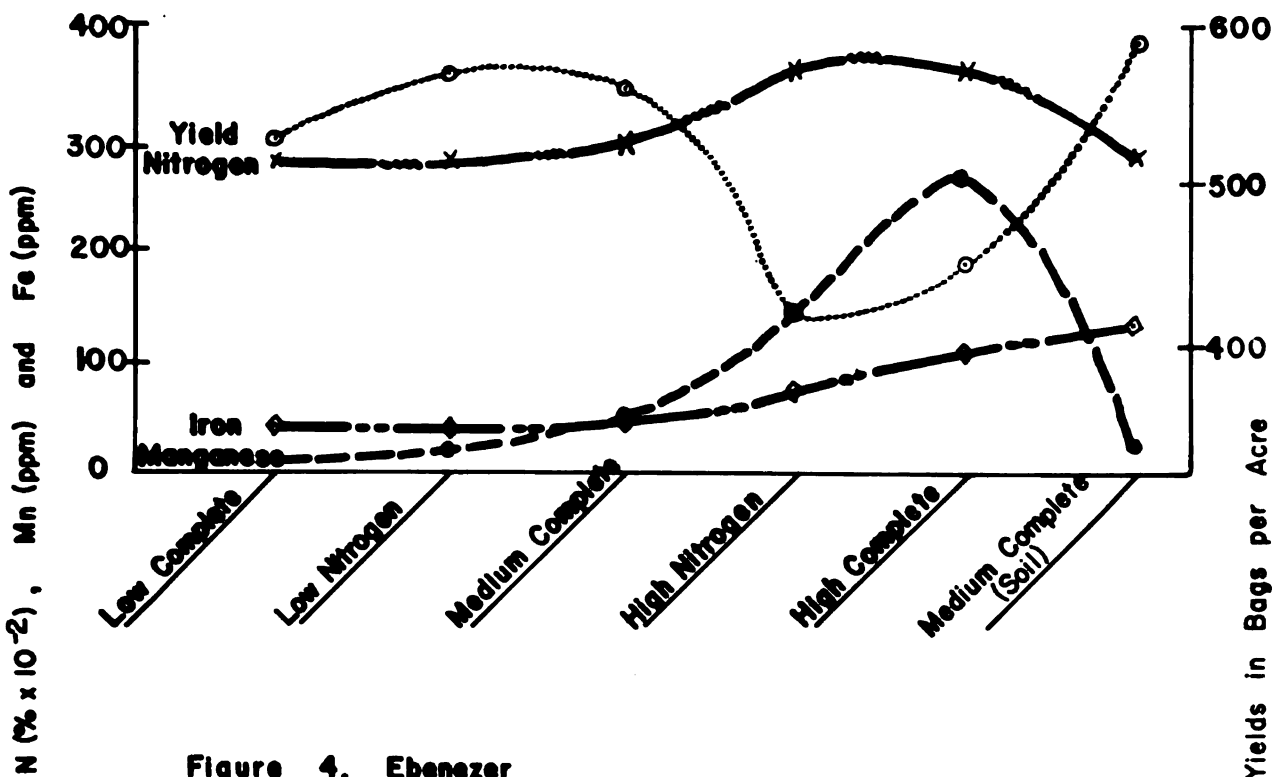
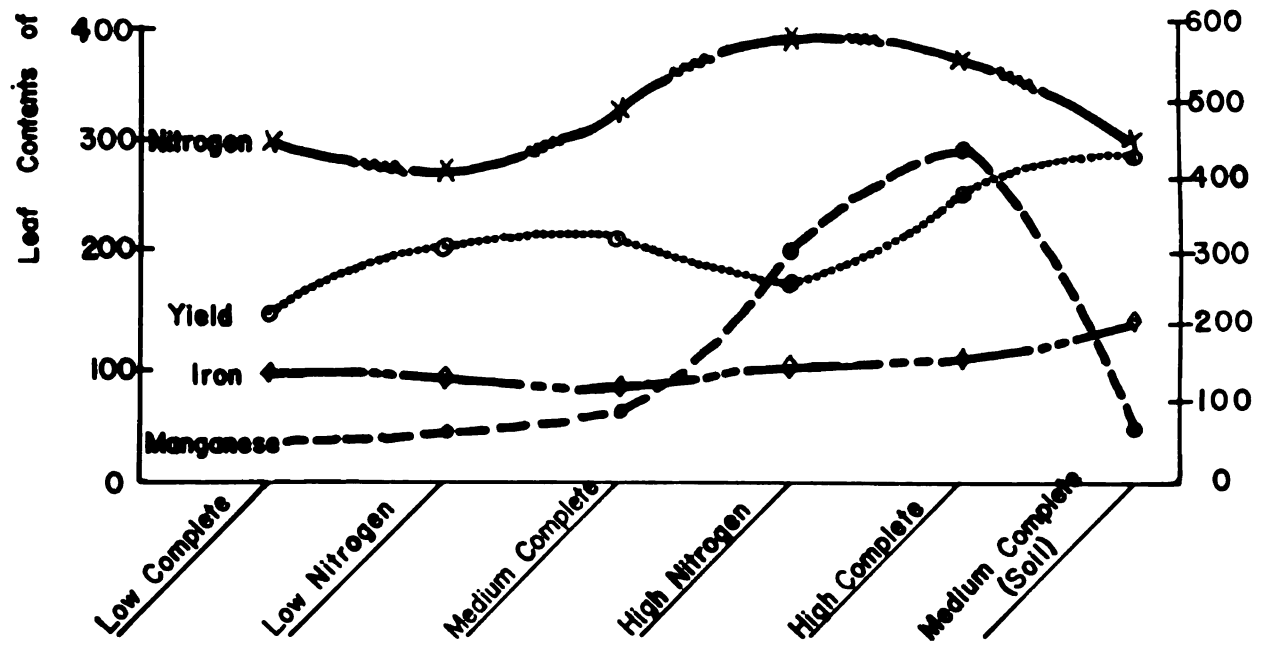


Figure 4. Ebenezer



Figures 3, 4. The Influence of Nitrogen Application on the Nitrogen, Manganese and Iron Contents of the Leaves and their Relation to Yield. 1953.

panying a rather marked increase in manganese content of the leaves and their relation to the yield of bulbs, emphasizing that apparently small changes in the nitrogen content of a crop may be associated with important changes in the yield of the crop. It is probable that the increased nitrogen content of the leaves is the result rather than the cause of growth reduction, due to the toxic concentration of manganese in the tissues. It may be noticed that although resulting in an increase in leaf manganese content, the high levels of the nutrients other than nitrogen (supplied in the high complete mixture) appeared to ameliorate the toxic effects of manganese with the result that yields were slightly increased. This effect was much more pronounced with Ebenezer than with the Downing variety. One of the reasons why Ebenezer was less susceptible to the maleffects of high nitrogen application may have been due to the fact that Ebenezer consistently contained about twice the concentration of iron found in Downing, and despite higher average contents of manganese, was able to respond to applied phosphorus to a greater degree than was the Downing variety, as shown in Figures 5 and 6. While the Downing Yellow Globe variety was increased in yield from 574 to 611 bags per acre, an increase of 6.4 per cent, the Ebenezer variety was increased from 322 bags to 393 bags per acre, an increase of 22 per cent, when the phosphorus was increased from the medium to the high level of application.

Figure 5. Downing Yellow Globe

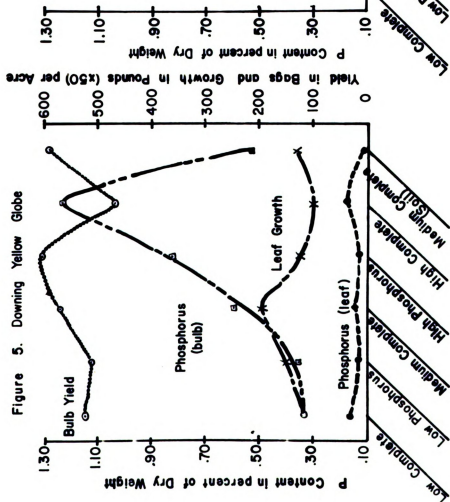
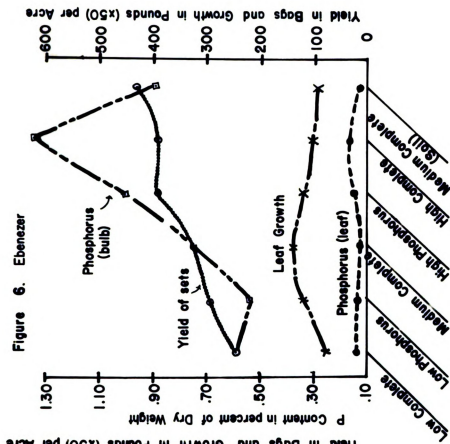


Figure 6. Ebenezer



Figures 5, 6. Influence of Phosphorus Application on Phosphorus Content, Growth and Yield 1953

The yield data in Table XII suggest that for the Downing variety nitrogen even at the low level was detrimental to bulb growth, except when used in connection with the medium levels of the other nutrients, as shown by comparison of the bulb yields for the low complete and low nitrogen treatments, and since the high level of phosphorus was one of the most beneficial treatments, a nitrogen phosphorus relationship is suggested.

Iron contents of the leaves and bulbs was found to have been increased with increasing rates of nitrogen application, but to a lesser extent than manganese, indicating that the high levels of manganese found in the plant did not interfere with iron absorption, though possibly with its availability (84). The leaves of the plants grown in the high nitrogen treatment were slightly pale compared to those in soil plots. The greenest leaves in both years were found in the soil plots, and the plants from these plots were found to have the highest iron contents, and a relatively lower manganese content. This is additional evidence that the high manganese contents of the plants grown with high nitrogen levels exhibited manganese toxicity which resulted from interference with iron absorption or utilization. It appears that Ebenezer was considerably more tolerant to high nitrogen applications than was Downing, and that increasing the quantity of other nutrients applied resulted in a pronounced increase in bulb yields, even with increased manganese concentrations in the leaves (Figures 3 and 4).

From this it would appear that on sandy soils with little buffering capacity, applications of large amounts of nitrogen may result in a high absorption of manganese which may be toxic to onions. It is possible that nitrogen might be of some use in facilitating the absorption of manganese by other crops on sandy soils, and might aid the plant in acquiring adequate manganese on overlimed sandy soils. Perhaps this effect of nitrogen would not be found on muck soils due to their high buffer capacity.

Manganese was the only nutrient other than nitrogen which was found to increase the nitrogen content of the leaves, and this effect was noted only in the Downing variety, and agrees with the results of other workers on peach (36), on grasses (14), and with oats (32). The nitrogen contents of the crops grown in 1952 were much lower in both leaf and bulb than those grown in the same plots the following season. Downing showing a larger increase in nitrogen than Ebenezer. The variation in nitrogen content as a per cent of the mean for all treatments was greater the first than in the second season, and was found in every case to be approximately 50 per cent greater in the bulbs than in the leaves. One of the possible explanations for the lack of injury from nitrogen in the 1952 crop may be due to the fact that iron was supplied at the rate of 20 pounds per acre in 1952, and at the rate of four pounds per acre in 1953.

Phosphorus:- The high phosphorus treatment resulted in a 134 per cent increase in the phosphorus contents of the bulbs of Downing and a 92 per cent increase in the phosphorus contents of the bulbs of the Ebenezer, but had no appreciable effect on the phosphorus contents of the leaves of either variety, in the second crop. Neither nitrogen nor potassium contents of the plants were significantly altered as a result of increased phosphorus applications, but the calcium contents were increased 21 per cent in the leaves of the Downing variety and 13 per cent in the leaves of Ebenezer, with the high phosphorus treatment. The calcium contents of the bulbs of both varieties were reduced, possibly as a result of growth dilution. The boron, manganese, iron, and sodium contents were little affected by variation in the quantity of applied phosphorus, although Biddulph has attributed iron deficiency to high phosphorus contents in the plant (12) and in the growing medium (11).

The high complete treatment resulted in the highest phosphorus contents of the bulbs, followed by the high levels of phosphorus, potassium, sulfur and manganese in both varieties, and by zinc in the Downing variety. The bulbs of both varieties from the soil plots were relatively high in phosphorus content. The increase in phosphorus content resulting from the application of the high levels of nitrogen, manganese, zinc, and the

complete treatments were likely due to reduced growth, but the other instances of increased bulb phosphorus were accompanied by increased bulb yields.

In Figure 5 is shown the relationship between phosphorus application, growth and yield, and phosphorus contents of leaves and bulbs in the Downing variety. Leaf growth was not affected in the same manner as bulb yield with increasing applications of phosphorus. As shown in Figure 6, a more nearly linear relationship between bulb phosphorus content and yield was encountered in the Ebenezer than in the Downing variety.

Potassium: - Although phosphorus application resulted in an increase phosphorus content only in the bulbs, high potassium applications doubled the potassium content of both leaves and bulbs in both varieties. Potassium influenced its own absorption more than it was influenced by any other nutrient. Potassium had no influence on the nitrogen content except to reduce it slightly where potassium additions increased yields. Compared to the low level of application, the high level of potassium increased the phosphorus contents of Downing leaves and bulbs despite significantly increased growth.

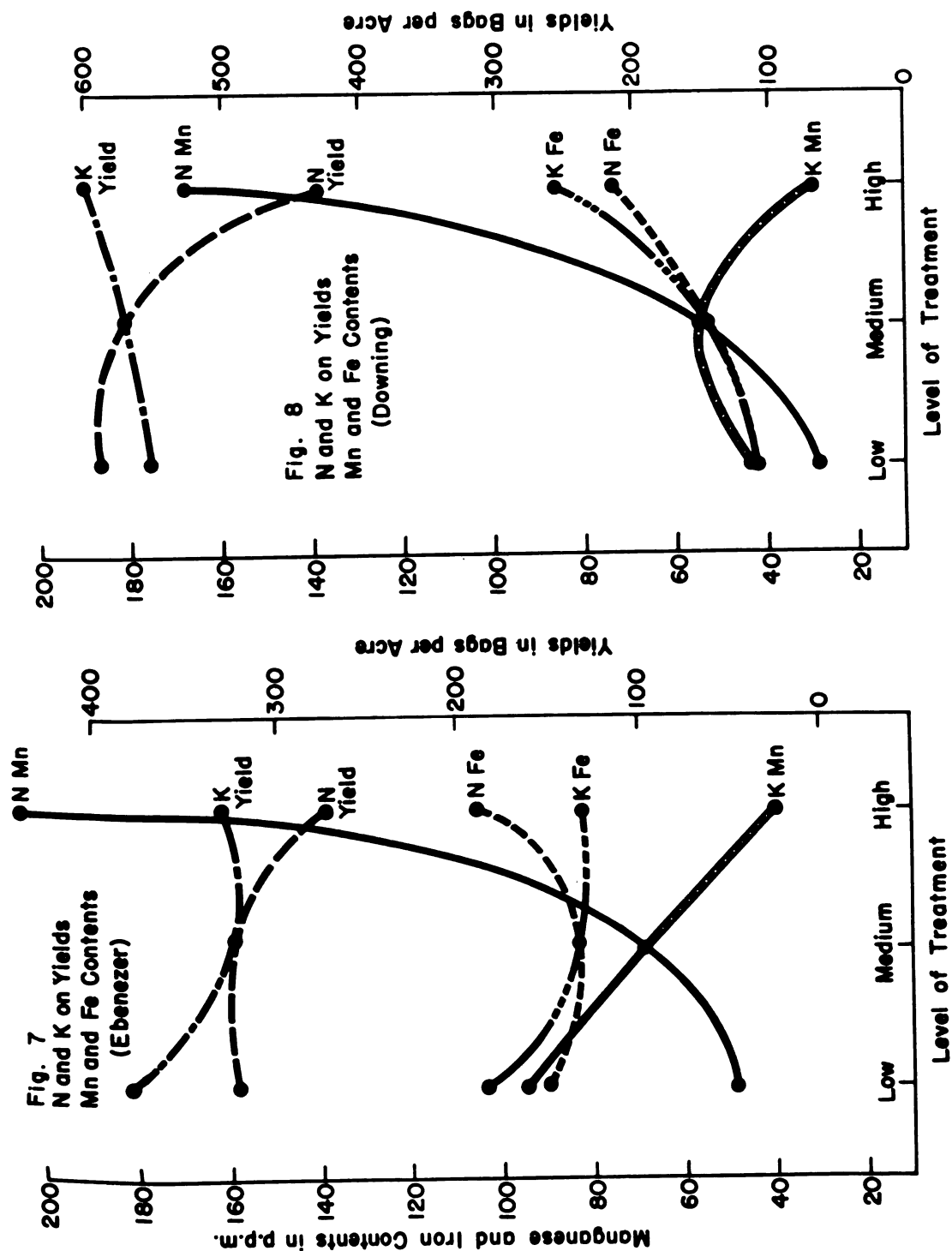
Added potassium significantly reduced the calcium, and to a greater extent, the magnesium contents of the leaves, but had little

effect on the bulb contents of these two nutrients. Although the amount by which magnesium was reduced by the high potassium treatments was small per unit of potassium concentration increase, as shown in Figure 2, the trend was, nevertheless, definite and was not affected by the increased nutrient content in the high complete treatment. Even when the leaf growth was depressed by the high complete treatment, potassium contents were highest in both varieties and the magnesium content was lowered. This problem of reduced magnesium contents as a result of potassium application is of importance with crops other than onions, and has been reported by other investigators (16, 17, 25, 26, 27, 29, 30, 34, 42, 68).

A reduction in the sodium contents in the plants of both varieties was found as a result of high potassium application. Boron contents were reduced about one-fifth in the leaves of both varieties, while manganese was reduced 32 per cent in the leaves, and 21 per cent in the bulbs of the Downing variety, and 50 and 19 per cent in leaves and bulbs respectively in the Ebenezer variety. Daniel (36) found that a mixture of nitrogen and potassium increased the manganese contents of peach leaves to a greater extent than nitrogen alone, and that a complete mixture containing nitrogen, potassium and phosphorus resulted in a 90 per cent increase in manganese concentration over a mixture of any two of the nutrients.

Iron was increased almost 50 per cent in the leaves and 33 per cent in the bulbs of the Downing variety, and 21 per cent in Ebenezer leaves with the high potassium treatment. The tendency of potassium to be associated with increased iron contents of plants has been reported by other workers (49, 61, 68, 81). The increase in iron contents with increased application of potassium might be interpreted as a function of a reduction of manganese contents due to the relatively large K:N ratio in the fertilizer treatment. In this connection it might be pointed out that each increment of applied nitrogen resulted in significantly increased manganese accumulations. If it may be assumed that nitrogen directly increased nitrogen accumulation, it is probable that it also served indirectly to favor manganese absorption by countering the depressive effects of potassium upon manganese.

In Figures 7 and 8 are shown data which serve to substantiate the suggestion that nitrogen and potassium acted oppositely with respect to manganese and iron accumulation and hence upon yield. These figures show in addition that although the degree of response with the two varieties was different, the directions of the responses were similar. These figures show that nitrogen increased both iron and manganese accumulation in the leaves of both varieties, the manganese accumulation presumably resulting in decreased usefulness of the iron contained with a



Figures 7, 8 Relation of Nitrogen and Potassium Application to Manganese, Iron Accumulation and Yield 1953

resultant yield depression. In Ebenezer potassium additions depressed both manganese and iron, but the manganese was depressed relatively more than the iron with the result that potassium resulted in increased yields, whereas nitrogen additions increased the accumulation of manganese to a much greater extent than they did the accumulation of iron, with resulting low yields. In Downing, however, potassium additions, in addition to depressing manganese accumulation, increased the absorption of iron with the result that yields were increased to a greater extent than they were in Ebenezer.

Nevertheless, Ebenezer appeared to be affected relatively less by the high nitrogen applications than was Downing, and it is suggested that this is the result of the failure of the high potassium application to as effectively promote an increased iron uptake in Ebenezer as it did in Downing. Loehwing (61) has pointed out that sap acidity and iron solubility is increased with plant potassium content, while Sideris found both iron and potassium contents to be increased with high potassium application (81), and found that high plant pH values associated with high nitrate absorption to be as effective as high manganese in the culture solution in precipitating iron in pineapple roots (82).

The effect of nitrogen in increasing iron and the effect of potassium in depressing manganese accumulation was more pronounced

in the Ebenezer than it was in the Downing variety. High nitrogen treatment reduced the yields of Downing more than it did the yield of Ebenezer, apparently because iron was increased to a greater extent in Ebenezer than it was in Downing Yellow Globe.

From these relationships the interactive influence of nitrogen and potassium on the accumulation of the catalytic fertilizers manganese and iron is quite apparent. It indicates an additional need for care in balancing these nutrients in fertilizer practice for sensitive crops. These relationships apparently vary depending on either the variety or the stage at which the crop is harvested. In addition, the evidence on the effect of potassium on magnesium absorption indicates a possibility that on soils that are initially low in magnesium, application of magnesium should be adjusted to compensate for the increased potassium application.

Magnesium:- Magnesium applications had no significant effect on the contents of nitrogen, copper, calcium, iron, boron or sodium. Despite an increase in yield of Downing bulbs, as a result of applying magnesium, the phosphorus concentration of the bulbs was increased by 68 per cent with the high rates of application. There has been some suggestion of a relationship between magnesium and phytin in the mineralization of soil phosphorus (35). It is recognized, of

course, that phytin is the principal form of stored phosphorus in many, if not all, seeds, usually in the form of salts with metals such as calcium or magnesium (40), and it is possible that some phosphorus is stored in bulbs in this form. The calcium and magnesium salts of phytic acid are sparingly soluble, and are concentrated in the outer coats of cereals and other seeds, providing a reserve of these nutrients for the growing plant (88).

The decrease in the potassium contents of Downing leaves as a result of high magnesium applications may be, in part at least, due to increased growth. No effect of magnesium application on the potassium content of Ebenezer leaves or bulbs was found. The fact that the magnesium concentration in Downing leaves was maintained with increased growth, suggests that high magnesium applications favored growth. The increased contents of magnesium in the leaves of the Ebenezer variety may have been due to an increase in concentration with a decreased growth. There was a tendency for magnesium applications to result in decreased manganese accumulations in the leaves of Downing as a result of increased growth, but in Ebenezer, despite decreased leaf growth, there was no change in the manganese.

Other than the significant increase in magnesium content in Ebenezer leaves with a high magnesium application, no nutrient was

found to increase the plant magnesium contents. All the nutrients at the high level, with the exception of manganese and zinc, resulted in decreased magnesium concentration in the leaves, presumably as a result of increased growth. Potassium caused a significant reduction in magnesium content that could be only partially accounted for in increased growth. The high magnesium application slightly reduced the iron content, and resulted in a 40 per cent reduction of the manganese concentration in Downing leaves. No effects of magnesium additions on the iron or manganese concentrations in the bulbs were found.

The magnesium contents found in the leaves and bulbs of the crop grown in 1953 were almost twice those found in the crop the previous year, in spite of an almost three-fold increase in bulb yield. In both years increased yields and plant contents of magnesium resulted from the high rates of magnesium application. These relationships are shown graphically in Figures 9 and 10 for the second crop.

Sulfur:- Sulfur had no significant effect when applied at various rates, as sulfate, on the nitrogen, potassium, copper, iron, boron or sodium contents of the leaves or bulbs of either variety. However, the application of sulfur resulted in increased phosphorus contents of the bulbs of both varieties. The magnesium contents of the leaves of the Downing variety were significantly reduced and the calcium contents

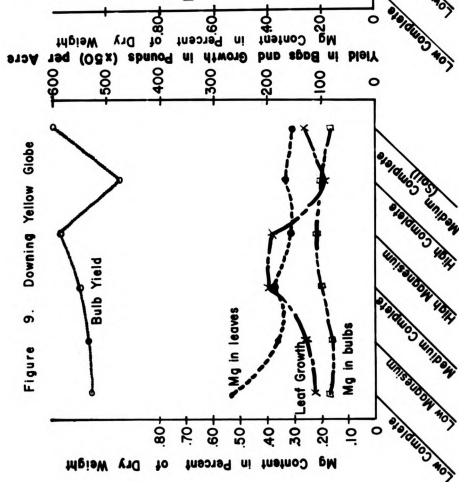
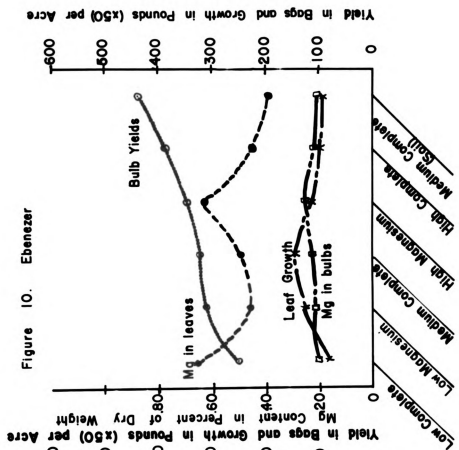


Figure 10. Ebenezer



Figures 9, 10. Influence of Magnesium Application on Magnesium Content and Growth 1953

were increased by sulfur application, while in Ebenezer leaves, the sulfur treatment significantly increased the calcium concentration, but had no effect on magnesium. No change in the bulb contents of either magnesium or calcium as a result of sulfur application was obtained. In Ebenezer the calcium content was increased, despite increased leaf and bulb growth. Although the increase in bulb contents of manganese was statistically significant in both varieties as a result of increased sulfur application, probably the difference was too small to be of physiological importance. The leaf contents of manganese were not significantly increased by applied sulfur.

Manganese:- The high manganese treatment resulted in increased nitrogen contents of Downing leaves and calcium contents of Ebenezer leaves, with increased leaf growth in both varieties. No other significant influence of manganese on plant composition was found. Applied manganese did not significantly influence its own absorption, or that of iron.

Depressions in manganese content resulted from the application of high levels of potassium, magnesium, copper and manganese in both varieties, and by zinc in the Downing variety. The contents of manganese in the plants grown in the soil plots were low. Dilution by increased growth may have been responsible for a part of the reduction

in manganese concentration due to applications of phosphorus, potassium and copper, but manganese concentration was decreased in the face of reduced growth as a result of the application of manganese and zinc at the high rate.

Zinc:- Zinc at the high rate of application resulted in increased concentrations in the plant of nitrogen, phosphorus and potassium in both varieties, and of calcium and manganese in Ebenezer probably chiefly through a yield reduction. Magnesium, sodium and boron contents were slightly reduced in both varieties, and calcium and manganese in the Downing variety, by added zinc. The application of zinc at the high rate reduced yields both seasons, indicating that in sandy, poorly buffered soils the quantities of zinc which may safely be applied to onions is much less than that frequently applied to the same type of soils supporting citrus, for the control of white bud of corn (77), or for correcting zinc deficiency in onion on muck soils (69).

SUMMARY AND CONCLUSIONS

A modified sand culture experiment involving the influence of three levels of application of nitrogen, phosphorus, potassium, sulfur, magnesium, copper, manganese and zinc, upon the growth and composition of two varieties of onions was conducted for two growing seasons. The nutrient carriers were selected to provide variation only in the nutrient being considered as a variable, all others being equal in concentration. The leaves and bulbs, separated at harvest, were separately analyzed for their contents of total ash, and nitrogen, phosphorus, potassium, magnesium, copper, manganese, calcium, iron, boron and sodium.

Bulbs of Downing Yellow Globe grown with the 20 different nutrient combinations were planted the following season for seed production. Sets of Ebenezer onions grown with the same 20 nutrient combinations were planted the following season in a muck soil for the production of a mature bulb crop.

No significant nutrient influence on the production or viability of seed was found. Sets of Ebenezer produced with the high sulphur and with the high manganese treatments resulted in reduced bulb yields and fewer double bulbs when grown to maturity in a muck soil.

In the course of the analytical work a procedure was developed for evaluating specific interferences by potassium, calcium, magnesium and

sodium in various combinations of concentration in the photometric determination of these elements.

Growth and composition of onions in a modified soil culture medium were found to be associated with treatment and related to each other. There were significant differences due to variety.

1. Nitrogen was found to increase growth and yield when it was limiting and the plants were able to absorb sufficient iron to balance an enormous increase in accumulated manganese associated with a high nitrogen application. Where yield was reduced by high nitrogen applications, a five- to ten-fold increase in the manganese contents were found, though definite toxicity symptoms did not appear.

2. Phosphorus was found to be very beneficial to bulb yield while at the same time reducing top growth, which indicated that this nutrient probably contributed to early bulbing.

3. Potassium increased both leaf growth and bulb yields, and tended to counteract the detrimental effect of high nitrogen by depressing manganese and increasing iron absorption and utilization. Potassium influenced its own absorption more than any other nutrient, and was the most significant nutrient in altering the magnesium content of the plant. Potassium application at the high level reduced both the magnesium and sodium contents of the foliage.

4. Magnesium applications increased both leaf and bulb yield, and the magnesium contents of the leaves.

5. Application of sulfur increased yields, and phosphorus and calcium contents of leaves, and manganese contents of the bulbs.

6. Copper applications affected yields erratically and had no significant influence on the copper content of the plant.

7. Manganese increased yields the first year, but decreased them the second, which may have been related to a reduced iron application the second season. Possibly as a result of reduced growth, the nitrogen, phosphorus and calcium contents were increased in the plants the second year. Manganese treatment was without significant effect on manganese composition.

8. Zinc depressed yields both years, and possibly as a result increased contents of phosphorus were found in the bulbs. but it caused a decrease in the boron content of one variety.

9. Zinc applications resulted in the depression of the potassium contents of the leaves of the Downing Yellow Globe variety, and increased the calcium content in the Ebenezer variety.

LITERATURE CITED

1. Amin, F. Y. A study of the influence of certain nutrients on growth and flowering of Hyacinth orientalis Linn. Thesis, Ph.D. Michigan State College. 1952.
2. Association of Official Agricultural Chemists. Official and tentative methods of analysis of the Association of Agricultural Chemists, 6th Ed., Washington, D. C. 1945.
3. Barnette, R. M., and J. D. Warner. A response of chlorotic corn plants to zinc sulfate applied to the soil. *Soil Sci.* 39: 145-156. 1935.
4. Barbier, G. The mineral nutrition of the plant as a function of the chemical composition of the medium. *Ann. Agron. (N.S.)* 6: 568-586. 1936 (*Chem. Abst.* 30: 8479).
5. Beaumont, A. B., M. E. Snell, W. L. Doran and A. J. Bourne. Onions in the Connecticut Valley. *Mass. Agr. Exp. Sta. Bul.* 318. 1935.
6. Beeson, Kenneth C. The mineral composition of crops with particular reference to the soils in which they were grown. *U.S.D.A. Misc. Pub.* 369. 1941.
7. Bennett, J. P. Iron in leaves. *Soil Sci.* 60: 91-105. 1945.
8. Bernstein, Leon, and A. D. Ayers. Salt tolerance of five varieties of onions. *Proc. Amer. Soc. Hort. Sci.* 62: 367-370. 1953.
9. Bertrand, G. On catalytic fertilizers. *Jour. Soc. Chem. Indust.* 28 (13): 274. 1909.
10. _____. Influence of manganese on the nitrogen nutrition of plants. *Compt. Rend. Agr. France* 21: 1215-1222. 1935.
11. Biddulph, O. Interrelations between iron and phosphorus in plant nutrition. *Oregon State College, Colloquium, Nutrition* 24-27. 1948.

12. Biddulph, O., and C. G. Woodbridge. Uptake of phosphorus by bean plants with particular reference to the effect of iron. *Plant Phys.* 27: 431-444. 1952.
13. Bishop, E. R. Calcium and phosphorus contents of some Alabama vegetables. *Jour. Nutr.* 8(2): 239-245. 1934.
14. Bishop, W. B. S. The distribution of manganese in plants and its importance in plant metabolism. *Aust. Jour. Exp. Biol. and Med. Sci.* 5(2): 125-141. 1928.
15. Blackmon, G. H. Pecan variety response to different soil types and localities: zinc treatments. *Fla. Agr. Exp. Sta. Ann. Rpt.* 74-75. 1935.
16. Boynton, Damon, and A. B. Burrell. Potassium-induced magnesium deficiency in the McIntosh apple tree. *Soil Sci.* 58: 441-454. 1944.
17. _____, and T. W. Embleton. Further studies on magnesium deficiency of the apple and its control. *Proc. Amer. Soc. Hort. Sci.* 55: 21-26. 1950.
18. Boullanger, E. The action of sulfur on plants. *Compt. Rend. Acad. Sci. (Paris)*, 154(6): 369-370. 1912.
19. _____. Studies on catalytic fertilizers. *Ann. Sci. Agron.* 4 ser. 1. 1912.
20. Bremer, H. Ueber zeibelbildung und abreifung der Kuchen-zweibel. *Angew. Bot.* 18: 204-231. 1936.
21. Brown, J. G., O. Lilleland, and R. K. Jackson. Further notes on the use of flame methods for the analysis of plant material for potassium, calcium, magnesium and sodium. *Proc. Amer. Soc. Hort. Sci.* 56: 12-22. 1950.
22. Brown, P. E., and G. A. Minges. The effect of some manganese salts on ammonification and nitrification. *Soil Sci.* 2(1): 67-85. 1916.

23. Burstrom, Hans. The catalysis of heavy metals in the assimilation of nitrate. *Planta* 29: 292-305. 1939.
24. Butler, O. Bordeaux mixture. II. Stimulatory action. *New Hampshire Agr. Exp. Sta. Tech. Bul.* 21. 1922.
25. Cain, J. C., and Damon Boynton. Some effects of season, fruit crop and nitrogen fertilization on the mineral composition of apple leaves. *Proc. Amer. Soc. Hort. Sci.* 51: 13-22. 1948.
26. _____. The effect of nitrogen and potassium fertilizers on the performance and mineral composition of apple trees. *Proc. Amer. Soc. Hort. Sci.* 62: 46-52. 1953.
27. Campbell, J. D. Differential cation absorption and yield response by vegetable crops grown at various levels of calcium, potassium and sodium. Thesis, Ph.D., Michigan State College. 1953.
28. Carolus, R. L. Effect of certain ions used singly and in combination on the growth and potassium, calcium and magnesium absorption of the bean plant. *Plant Phys.* 13(2): 349-363. 1938.
29. _____ and B. E. Brown. Magnesium deficiency. I. The value of magnesium compounds in vegetable production. *Va. Truck Exp. Sta. Bul.* 89. 1935.
30. _____. The relation of potassium, calcium and sodium to magnesium deficiency. *Proc. Amer. Soc. Hort. Sci.* 33: 595-599. 1936.
31. Cochran, Wm. G., and Gertrude M. Cox. *Experimental Designs.* John Wiley and Sons, New York. 1950.
32. Coic, Y., M. Coppernet and S. Voix. Effects of nitrogen on the absorption of manganese by oats. *Compt. Rend.* 230, 1610-1611. 1950.
33. Comin, Donald. The response of some muck crops to the application of some minor elements. *Ohio Agr. Exp. Sta. Biomonthly Bul.* 29: 144-147. 1944.

34. Cromwell, S. T., and J. G. Hunter. Chlorosis in tomatoes. *Nature* 150: 606-607. 1942.
35. Cultrera, Rolando. The fertilizing power and the physiological function of magnesium. *Ann. Staz. Sper. Agrar. Modena (N.S.)* 5: 515-528. 1936.
36. Daniel, W. H. A study of the response of peach trees to potassium fertilization. Thesis, M. S., Michigan State College. 1948.
37. Eisenmenger, W. S., and E. B. Holland. The absorption by food plants of chemical elements important in human nutrition. *Mass. Agr. Exp. Sta. Ann. Rpt. Bul.* 339, 11. 1936.
38. Erkama, Jorma. On the effect of copper and manganese on the iron status of higher plants. *Trace Elements in Plant Physiology. Chronica Botanica Co., Waltham, Mass.* 1950.
39. Evans, H. J., and E. R. Purvis. An instance of manganese deficiency of alfalfa and red clover in New Jersey. *Jour. Amer. Soc. Agron.* 40: 1046-1047. 1948.
40. Fearon, W. R. *An Introduction to Biochemistry*, 3rd Ed. Grune and Stratton, New York. 1947.
41. Felix, E. L. Correction of unproductive muck by the addition of copper. *Phytopath.* 17(1): 49-50. 1927.
42. Garner, W. W., J. E. McMurtrey, C. W. Bacon, and E. G. Moss. Sand drown, a chlorosis of tobacco due to magnesium deficiency and the relation of sulfates and chlorides of potassium to the disease. *Jour. Agr. Res.* 23:27-40. 1923.
43. Gilbert, B. E. Normal crops and the supply of soil manganese. *R. I. Agr. Exp. Sta. Bul.* 246. 1934.
44. Gisiger, Leo. Deficiencies of minor elements caused by excesses. *Trace Elements in Plant Physiology.* 3(1): 18-29. *Chronica Botanica Co., Waltham, Mass.* 1950.

45. Goulden, Cyril H. *Methods of Statistical Analysis*, 2nd Ed.
John Wiley and Sons, New York. 1952.
46. Harmer, Paul M. *Muck soil management for onion production*.
Mich. Agr. Ext. Bul. 123. 1936.
47. Hartwell, B. L., and C. S. Damon. *The value of sodium when
potassium is deficient*. R. I. Agr. Exp. Sta. Bul. 177.
1919.
48. Hawthorne, L. R. *Fertilizer experiments with yellow Bermuda
onions in the winter garden region of Texas*. Texas
Agr. Exp. Sta. Bul. 524: 5-35. 1936.
49. Hopkins, E. F., and J. H. Gourley. *A study of the ash constituents
of apple fruits during the growing season*. Ohio Agr.
Exp. Sta. Bul. 519. 1933.
50. Iverson, V. E. *Two new materials in plant nutrition*. Proc. Amer.
Soc. Hort. Sci. 35: 763-767. 1938.
51. Iyer, C. R., R. Harihara, R. Rajagopalan, and V. Subramanyan.
*Role of organic matter in plant nutrition. II. Oxidizing
agents as fertilizers*. Proc. Ind. Acad. Sci. 13: 106-
122. 1934. (Chem. Abst. 29: 2645. 1934).
52. Jones, Linus H., Wm. B. Shephardson, and Charles A. Peters.
The function of manganese in the assimilation of nitrates.
Plant Phys. 24: 300-306. 1949.
53. Kenworthy, A. L. *Nutritional conditions of Michigan orchards:
A survey of soil analyses and leaf composition*. Mich.
Agr. Exp. Sta. Tech. Bul. 237. 1953.
54. Knott, J. E. *Growing onions on the muck soils of New York*.
N. Y. (Cornell) Agr. Exp. Sta. Bul. 510. 1930.
55. _____. *Some factors affecting the color and thickness of
onion scales*. Proc. Amer. Soc. Hort. Sci. 28: 318-
328. 1931.

56. Knott, J. E. Effect of certain mineral elements on the color and thickness of onion scales. N. Y. (Cornell) Agr. Exp. Sta. Bul. 552. 1933.
57. _____. Fertilizing onions on muck soils. N. Y. (Cornell) Agr. Exp. Sta. Bul. 650. 1936.
58. Kunkel, Robert. The effect of various levels of nitrogen and potassium on the yield and keeping qualities of onions. Proc. Amer. Soc. Hort. Sci. 50: 361. 1947.
59. Lloyd, J. W., and E. P. Lewis. Fertilizing twenty-five kinds of vegetables. Ill. Agr. Exp. Sta. Bul. 346. 1930.
60. Lucas, R. E. The effects of addition of sulfates of copper, zinc, and manganese on the absorption of these elements by plants grown on organic soils. Proc. Soil Sci. Soc. Amer. 10: 269-274. 1945.
61. Loehwing, Walter F. Calcium, potassium and iron balance in certain crop plants in relation to their metabolism. Plant Phys. 3(3): 261-272. 1928.
62. Magruder, Roy, and H. A. Allard. Investigations of regional adaptations of onion varieties. Seed World 39(9): 5-7. 1936.
63. Marsh, R. P., and J. W. Shive. Adjustment of iron supply to requirements of soybeans in solution culture. Bot. Gaz. 79: 1-27. 1925.
64. McCalla, A. G., and E. K. Woodford. Effects of a limiting element on the absorption of individual elements and on the anion: cation balance in wheat. Plant Phys. 13(4): 695-712. 1938.
65. Merrill, S. Jr., G. F. Potter, and R. T. Brown. Response of tung trees on Lakeland fine sand to less common elements. Proc. Amer. Soc. Hort. Sci. 62: 94-102. 1953.
66. Miller, L., and H. S. Mitchell. Correlation of copper and manganese contents of plants and mineral additions to the soil. Jour. Amer. Dietetic Ass'n. 7(3): 252-257. 1931.

67. Muckenhirn, R. J. Response of plants to copper, boron and manganese. *Jour. Amer. Soc. Agron.* 28: 824-842. 1936.
68. Nemec, Antonin. Potassium and magnesium deficiency phenomena in seedlings and cultures of pines. *Forstwiss. Centr.* 74: 160-166. 1942. *Biblio. Minor Elements I*, 4th Ed. 1203(1). 1948.
69. Nylund, R. E. The response of onions to soil and foliar applications of manganese and to soil application of other trace elements. *Proc. Amer. Soc. Hort. Sci.* 60: 283-285. 1952.
70. Powers, W. L., and L. K. Wood. The status of minor elements in Oregon soil fertility and plant nutrition. *Ore. Agr. Exp. Sta. Cir. of Inform.* 418. 1947.
71. Pugliese, A. Biochemical influence of manganese. *Atti. R. Inst. Incoragg. Napoli*, 6 ser. 65: 289-315. 1913. (Abst. *Biblio. Minor Elements I*, 4th Ed. 1391(1). 1948).
72. Quartarani, A. Copper as a biological element and as a fungicide. *Atti. Congolfili.* 10(1): 41-44. 1947.
73. Reuther, Walter, and P. F. Smith. A preliminary report on the relation of nitrogen, potassium and magnesium fertilization to yield, leaf composition and the incidence of zinc deficiency in oranges. *Proc. Amer. Soc. Hort. Sci.* 56: 27-33. 1950.
74. Richards, M. B. Manganese in relation to nutrition. *Biochem. Jour.* 24(5): 1572-1590. 1930.
75. Rippel, August. The iron chlorosis in green plants caused by manganese. *Biochem. Z.* 140: 315-322. 1923. (Abst. *Biblio. Minor Elements I*, 4th Ed. 1397(1). 1948).
76. Roberts, A. N., R. E. Stephenson, and S. E. Wadsworth. Effectiveness of lime in preventing scorch of Croft lilies during forcing. *Florists Exch., Hort. Trade World* 117, No. 17: 14-15, 23. 1951.
77. Rogers, L. H. The role of zinc in crop production. *Citrus Indust.* 27(12): 5, 9-12. 1946.

78. Seeley, John G. Nutrient deficiencies in Croft lilies. Florists Exch., Hort. Trade World 114(17): 62. 1950.
79. Shear, C. B., H. L. Crane, and A. T. Myers. Nutrient-element balance: Application of the concept to the interpretation of foliar analysis. Proc. Amer. Soc. Hort. Sci. 51: 319-326. 1948.
80. Sherman, G. Donald, and Paul M. Harmer. Manganese deficiency of oats on alkaline organic soils. Jour. Amer. Soc. Agron. 33(12): 1080-1091. 1941.
81. Sideris, C. P., and H. Y. Young. Effects of different amounts of potassium on growth and ash constituents of Ananas comosus (L.) Merr. Plant Phys. 20: 609-630. 1945.
82. _____. Effects of nitrogen on growth and ash constituents of Ananas comosus (L.) Merr. Plant Phys. 21: 247-270. 1946.
83. _____. Growth and chemical composition of Ananas comosus in solution cultures with different iron-manganese ratios. Plant Phys. 24: 416-440. 1949.
84. _____. Manganese interference in the absorption and translocation of radioiron in Ananas comosus. Plant Phys. 25: 307-321. 1950.
85. Somers, I. I., and J. W. Shive. The iron-manganese relation in plant metabolism. Plant Phys. 17: 582-602. 1942.
86. _____, S. G. Gilbert, and J. W. Shive. The iron-manganese ratio in relation to the respiratory CO₂ and deficiency-toxicity symptoms in soybeans. Plant Phys. 17: 317-320. 1942.
87. Staker, E. V. Progress report on the control of zinc toxicity in peat soils. Soil Sci. Soc. Amer. Proc. 7: 387-392. 1942.
88. Steele, C. C. Introduction to Plant Biochemistry. 2nd Ed. G. Bell and Sons, Ltd., London. 1949.

89. Strong, W. O., H. H. Zimmerley, and H. T. Cook. Onion culture. Va. Truck Exp. Sta. Bul. 72. 1930.
90. Stuart, N. W., and D. M. Griffin. Some nutrient deficiency effects in onions. *Herbertia* 11: 329-337. 1944.
91. Thomas, Walter, and Warren B. Mack. Misconceptions relative to the method of foliar diagnosis. *Proc. Amer. Soc. Hort. Sci.* 44: 355-361. 1944.
92. True, R. H., O. F. Black, and J. W. Kelly. Ash absorption by spinach from concentrated soil solutions. *Jour. Agr. Res.* 16(1): 15-25. 1919.
93. Twyman, E. S. The iron manganese balance and its effect on the growth and development of plants. *New Phytologist*. 45: 18-24. 1946.
94. Ware, L. M., and W. A. Johnson. Phosphorus studies with vegetable crops on different soils. *Ala. Agr. Exp. Sta. Bul.* 268. 1949.
95. Wilson, W. A. Relation of nitrate nitrogen to the carbohydrate and nitrogen content of onions. New York (Cornell) *Agr. Exp. Sta. Mem.* 156. 1934.

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